Engineering Numbers & Needs in the SADC Region

Engineering Numbers & Needs in the SADC Region

Engineering Numbers and Needs in the SADC Region

Approved at the Joint Meeting of SADC Ministers responsible for Education and Training, Science, Technology and Innovation in Windhoek, Namibia in June 2019.

The Southern African Development Community (SADC) Secretariat
SADC Headquarters
Plot No. 54385, CBD Square
Private Bag 0095
Gaborone, Botswana

Tel.: +267 395 1863
Fax.: +267 397 2848
Website: www.sadc.int

Citation: SADC. 2018. *Engineering Numbers and Needs in the SADC Region*. Gaborone, Botswana: SADC.

Table of contents

Glossary

Academia	Refers to the collective term for tertiary education institutions.
Academic	A teacher in a university or other tertiary institutions offering higher education qualifications.
BEng or BSc(Eng)	Bachelor of Engineering or Bachelor of Science in Engineering. The duration of study is usually a minimum of four years full time but can be five years.
Candidate Engineer-in-training Graduate-in-training	Terminology varies from country to country but refers to graduates who are registered as being in the training phase of their careers. It takes a minimum of three years from commencement of training in the workplace before graduates may apply to become professionally registered, but it may take a longer period of training to develop the level of competence required for professional registration. It must be noted that those in training may not work independently but must work under the supervision of registered professionals. In some countries it is compulsory to be registered as being 'in-training' during this phase, failing which experience gained will not be recognised, while in others registering bodies only engage with those ready for assessment for professional registration.
Coach	A guide who will develop specific skills required in the workplace. Skills transfer as a result of coaching in the execution of workplace tasks, translates directly to performance outcomes that are achieved over a short period of time.
Continuing Professional Development (CPD)	Engineering professionals are required to continue to develop professionally. A minimum number of CPD points is to be accumulated each year for an engineering professional to maintain his/her professional status.
Dublin Accord	Refers to an internationally agreed standard according to which qualifications relating to the education of engineering technicians are structured and accredited.
Engineer	Refers to someone holding a qualification that meets the standards for a professional Bachelor's degree in engineering recognised by the registration body.
Engineering practitioner	Three engineering occupations are considered in the study: engineers, engineering technologists and engineering technicians. Throughout this report the term 'engineering practitioner' will be used as the collective term to describe this group, whether professionally registered or not.
Engineering professional	Where reference is specifically made to registered professional engineers, engineering technologists and engineering technicians, the collective term of engineering professionals will be used to describe this group.
Engineering Technician	Refers to the someone holding a qualification that meets the standards for a national diploma or an advanced certificate in engineering recognised by the registration body.
Engineering Technologist or Incorporated Engineer	Refers to someone holding a qualification that meets the standards for a Bachelor of Technology degree or higher national diploma in engineering recognised by the registration body.
Higher education	Refers to undergraduate studies leading to the award of academic degrees and post-graduate qualifications, from Bachelor's degrees to doctoral level, at levels 8 to 10 on the SADC Qualification Framework. With the advent of universities of technology and polytechnics this has been expanded to include the award of advanced certificates, diplomas and higher diplomas at levels 6 and 7.
Industrial attachment	As part of a national diploma and some engineering degrees, there is a requirement for students to complete practical training in the workplace. This must be structured and controlled to ensure that students derive maximum benefit from the experience so that it enriches and amplifies their academic knowledge.
Learner	For the purpose of this study, a learner is someone enrolled in primary or secondary education.
Mentor	A wise and trusted advisor or guide who will support a less experienced person to chart a comprehensive career path and offer advice as and when required.
National Diploma	A three-year undergraduate engineering qualification offered by universities, universities of technology, polytechnics or other tertiary institutions usually consisting of four semesters of theory and one year of workplace experience, known as an industrial attachment in some countries.
Non-governmental organisation (NGO)	A not-for-profit agency not affiliated with any government or private sector entity, devoted to raising funds, managing resources and implementing projects with the goal of addressing social problems or serving particular constituencies. NGO activities also include research, information distribution, training, local organisation and community services, legal advocacy and lobbying for legislative change. NGO access to strategic information can be used as a critical lobbying tool to mobilise and build power in endeavours to address particular shortcomings or inequalities.
Professional body	A collective term referring to all organisations with professional interests in the engineering sector, including voluntary associations (VAs) and registering bodies (RBs). In some countries, the collective term professional engineering institution is used (PEI) but professional body is used in this document.
Professional registration	After engineering practitioners have obtained the required qualifications and experience, engineering registration boards register them in the following categories:

	▪ Professional Engineer ▪ Professional Engineering Technologist or Incorporated Engineer ▪ Professional, Registered or Certificated Engineering Technician depending on the country.
Public sector	National government, provincial government, local government, parastatals, extra-budgetary governmental institutions, social security funds and non-financial public enterprises.
Registering body	A body set up to regulate the performance of individuals or companies in the engineering sector.
Sector Education and Training Authorities (SETAs)	Training authorities which address training and skills development per sector in a structured manner.
Skills development levy	A payroll tax designed to finance training initiatives, in terms of the skills development strategy.
Small, Micro-and Medium Enterprises (SMMEs)	Small, micro- and medium enterprises combine formal and informal sector activities. The order varies from country to country. For instance, micro-, small and medium enterprises (MSMEs) is used in Lesotho, Mauritius and Mozambique.
Southern African Development Community (SADC)	A regional governmental organisation that promotes collaboration, economic integration and technical cooperation throughout Southern Africa. Member nations are Angola, Botswana, the Democratic Republic of Congo, Eswatini, Lesotho, Madagascar, Malawi, Mauritius, Mozambique, Namibia, Seychelles, South Africa, Tanzania, Zambia and Zimbabwe. The Comoros joined SADC after the commencement of this study and has not been included in the scope of work.
Student	For the purpose of this study, a student is someone enrolled in tertiary education.
Subvention	Refers to a grant of money or aid received from donors or government sources to top up the salaries of academics to make them more market related and attractive.
Supervisor	A person who manages or supervises work. In the context of engineering work a supervisor may double as a coach.
Sydney Accord	Refers to an internationally agreed standard according to which the Higher National Diploma or Bachelor of Technology in engineering are structured and accredited.
Tertiary education	Refers to a third level of education after completing secondary education. This may be in higher education enrolled in undergraduate studies or in trade schools or colleges completing a vocational qualification. Generally, certificates and diplomas are awarded by vocational institutions, while national diplomas and academic degrees are awarded by higher education institutions.
Voluntary Association	A voluntary association is an institute, institution, association or society established by engineering practitioners to achieve a common non-profit objective of creating awareness and sharing knowledge in their profession and areas of practice.
Washington Accord	Refers to an internationally agreed standard according to which professional Bachelor of Engineering degrees are structured and accredited.
Workplace training (candidate/graduate-in-training phase)	In the candidate or graduate-in-training phase, those who have already attained a recognised qualification in engineering are trained in the application of engineering principles and methods. They are given increasingly complex work and progressively more responsibility until they can accept professional responsibility and make engineering decisions appropriate to the category of professional registration to which they are striving.

Acronyms and abbreviations

ACEN	Association of Consulting Engineers of Namibia
ACEPS	Association for the Construction and Engineering Professionals of Seychelles
ACET	Association of Consulting Engineers Tanzania
ACEZ	Association of Consulting Engineers of Zambia
ACIC	Association Congolaise des Ingénieurs Civils (Congolese Association of Civil Engineers)
ADER	Agency for the Development of Rural Electrification
AEDOSA	Association of Engineers of DRC Origin in South Africa
AEMC	Associação de Empresas Moçambicanas de Consultoria (Association of Mozambican Consulting Companies)
AESAP	Architects, Engineers, Surveyors and Allied Professionals Registration Council
AfDB	African Development Bank
AGM	Annual General Meeting
AGOA	African Growth and Opportunity Act
AIDI	Africa Infrastructure Development Index
AIET	Agreement for International Engineering Technicians
ANHRD	Agency for National Human Resources Development
APEC	Asia-Pacific Economic Cooperation
APET	Associação Professional Engenheiros Técnicos Angola
ARC	Agricultural Research Council
ARM	Madagascar Roads Authority
ARVs	Anti-Retroviral Drugs
ASDS	Agricultural Sector Development Strategy
ASSIAC	L'Association des Ingénieurs Agronomes du Congo (Association of Agricultural Engineers of the Congo)
ASSITAC	L'Association des Ingénieurs Techniciens Agronomes du Congo (Association of Agricultural Technical Engineers of the Congo)
AU	African Union
BCET	Botswana College of Engineering and Technology
BIE	Botswana Institution of Engineers
BIUST	Botswana University of Science and Technology
BNCQF	Botswana National Credit and Qualifications Framework
BoE	Board of Engineers
BQA	Botswana Qualification Authority
BRT	Bus Rapid Transit
BUAN	Botswana University of Agriculture and Natural Resources
C&G	City and Guilds

CAADP	Comprehensive Africa Agriculture Development Programme
CAMES	Conseil Africain et Malgache pour l'Enseignement Supérieur (African and Malagasy Council for Higher Education)
CBD	Central Business District
CBE	Council for the Built Environment
CDE	Centre for Development and Enterprise
CEB	Central Electricity Board
CESA	Consulting Engineers South Africa
CFMK	Chemin de Fer Matadi-Kinshasa
CHE	Council for Higher Education
CIA	Central Intelligence Agency
CIC	Construction Industry Council Eswatini
CIDB	Construction Industry Development Board
CIF	Construction Industries Federation of Namibia
CIFOZ	Construction Industry Federation of Zimbabwe
CMT	Cut, Make, Trim
coltan	columbite-tantalite
COMESA	Common Market for Eastern and Southern Africa
CPD	Continuing Professional Development
CRPE	Council of Registered Professional Engineers
CTIA	Cape Town International Airport
CWA	Central Water Authority
CZI	Confederation of Zimbabwe Industries
DOEs	Domestic Oriented Enterprises
DRC	Democratic Republic of the Congo
DSL	Digital Subscriber Line
DUAT	'use right to land'
DVDA	Direction des Voies de Desserte Agricole
DWS	Department of Water and Sanitation
EAB	Engineering Accreditation Board
ECN	Engineering Council of Namibia
ECSA	Engineering Council of South Africa
ECZ	Engineering Council of Zimbabwe
EDB	Economic Development Board
EEC	Eswatini Electricity Corporation
EHEA	European Higher Education Area
EIT	Institution of Engineers Tanzania
EITI	Extractive Industries Transparency Index
EIZ	Engineering Institution of Zambia
ENAEE	European Network for Accreditation of Engineering Education
ENDE-EP	National Electricity Distribution Company
EngRB	Engineering Registration Board
EOEs	Export Orientated Enterprises
EPA	Engineering Professions Association of Namibia
EPC	Engineering, Procurement and Construction
EPTC	Eswatini Post and Telecommunications Corporation
EPZ	Export Processing Zone
ERB	Engineers Registration Board

ESCOM	Electricity Supply Corporation of Malawi Ltd
ESCOT	Eswatini College of Technology
Eskom	Electricity Supply Corporation (South Africa)
ESP	Economic Stimulus Programme
ESPs	Écoles Supérieures Polytechniques
ESSA	École Supérieure des Sciences Agronomiques
EST	Est. – an abbreviation used for Estimated in graduation tables in country reports
EU	European Union
EWSC	Eswatini Water Services Corporation
FANR	Food, Agriculture and Natural Resources Directorate (SADC)
FAO	Food and Agriculture Organization (UN)
FDI	Foreign Direct Investment
FEANI	European Federation of National Engineering Associations
FEC	Federation of Congolese Enterprises
FMCGs	Fast-Moving Consumer Goods or Consumer Packaged Goods
FNOIM	Federation Nationale des Organisation d'Ingeniéurs Malagasy (Federation of Engineering Organisations)
FTTB	Fibre To The Business
FTTH	Fibre To The Home
FTTP	Fibre To The Premises
GBI	Greenbelt Initiative
GDP	Gross Domestic Product
GFCF	Gross Fixed Capital Formation
GVA	Gross Value Added
HDPE	High-density polyethylene
HIE	Higher Education Institution
HEMIS	Higher Education Management Information System
HEPSSA	Higher Education Partnerships in sub-Saharan Africa Programme
HIV/AIDS	Human Immunodeficiency Virus/Acquired Immunodeficiency Syndrome
HPP	Harambee Prosperity Plan
HR	Human Resources
ICT	Information and Communication Technologies
IEA	International Engineering Alliance
IEM	Institution of Engineers Mauritius
IETA	International Engineering Technologists Agreement
IHSM	Institut Halieutique des Sciences Marines
ILO	International Labour Organization
IMF	International Monetary Fund
IoE	Internet of Everything
IoT	Internet of Things
IPAP	Industrial Action Policy Plan
IPD	Initial Professional Development
IPEA	International Professional Engineers Agreement
IPER	International Professional Engineers Register
IPP	Independent Power Producer
IRCCOP	Regulatory Institute for Civil Construction and Public Works
IRP	Integrated Resource Plan
IRPET	International Register of Professional Engineering Technologists
ISIC	International Standard Industrial Classification
ISTA	Institut Supérieur de Techniques Appliquées
ISTs	Instituts Supérieurs de Technologie
IST-T	Institut Supérieur de Technologie d'Antananarivo
ISUTC	Instituto Superior de Transportes e Comunicações
IT	Information Technology
JIRAMA	Jiro sy Rano Malagasy
JV	Joint Venture
KIA	Kamuzu International Airport
KPIs	Key Performance Indicators
LAE	Lesotho Association of Engineers
LEC	Lesotho Electricity Company
LFS	Labour Force Survey
LHDA	Lesotho Highlands Development Authority
LHWP	Lesotho Highlands Water Project
LMD	Licenciate, Master's and Doctorate
LNDC	Lesotho National Development Corporation
LNG	Liquefied Natural Gas
LP	Lerotholi Polytechnic
LPG	Liquified Petroleum Gas
MAV	Mineral Asset Valuations
MDGS	Malawi Growth Development Strategies
MEI	Malawi Engineering Institution
MHILT	Ministry of Habitat, Infrastructure & Land Transport
MIE	Malawi Institution of Engineers
MIREMPET	Angolan Ministry of Mineral Resources and Petroleum
MNOs	Mobile Network Operators
MNRE	Ministry of Natural Resources and Energy
MOU	Memorandum of Understanding
MQA	Mauritius Qualifications Authority
MSMEs	Micro, Small and Medium Enterprises
MTC	Ministry of Transport and Communications
MTCAPM	Ministry of Tourism, Civil Aviation, Ports & Marine
MTL	Malawi Telecommunications Limited
MUST	Malawi University of Science and Technology
MVA	Manufacturing Value Added
N/A	Not applicable
NACTE	National Council for Technical Education
NASE	Namibian Society of Engineers
NATMAP	National Transport Master Plan 2050
NCC	National Construction Council (Tanzania)
NCC	National Council for Construction (Zambia)
NCIC	National Construction Industry Council

NDP	National Development Plan
NEAT	National Engineering Advisory Team
NEPAD	New Partnership for Africa's Development
NGO	Non-Governmental Organisation
NHBRC	National Home Builders Registration Council
NHRDS	National Human Resource Development Strategy
NIP	National Infrastructure Plan
NISTI	National Institute for Science, Technology and Innovation
NPE	New Energy Policy
NQF	National Qualifications Framework
NRZ	National Railways of Zimbabwe
NSDP	National Strategic Development Plan
NUL	National University of Lesotho
NUST	Namibia University of Science and Technology
NWSMP	National Water and Sanitation Master Plan
NWTGC	North West Transmission Grid Connection
OEA	Ordem dos Engenheiros de Angola
OEM	Original Equipment Manufacturer
OET	Ordem dos Engenheiros Técnicos (Portugal)
OIM	Order of Malagasy Engineers
ONATRA	Office National des Transports (National Transport Agency)
OrdEM	Ordem dos Engenheiros de Moçambique
OSD	Occupation Specific Dispensation
PB	Professional Body
PENAMT	Strategic National Accessibility, Mobility and Transport Plan
PET	Polyethylene terephthalate
PGM	Platinum Group Metals
PIDA	Programme for Infrastructure Development in Africa
PNIA	National Agricultural Investment Plan
PNSD	National Strategic Development Plan
PPADB	Public Procurement and Asset Disposal Board
PPP	Purchasing Power Parity
PPPs	Public-Private Partnerships
PRASA	Passenger Rail Agency of South Africa
PUC	Public Utility Company
PV	Photovoltaic
PVC	Polyvinyl chloride
QCTO	Quality Council for Trades and Occupations
QLFS	Quarterly Labour Force Survey
RA	Roads Authority
RBs	Registering Bodies
RED	Regional Electricity Distributor
RIDMP	Regional Infrastructure Development Master Plan
RISDP	Regional Indicative Strategic Development Plan
RPL	Recognition of Prior Learning
SA WISE	Association of South African Women in Science and Engineering
SAAES	Swaziland Association of Architects, Engineers and Surveyors
SACPE	South African Council of Professional Engineers
SADC	Southern African Development Community
SADCQF	SADC Qualifications Framework
SADP	Smallholder Agricultural Development Programme
SAFEO	Southern African Federation of Engineering Organisations
SAICC	Swaziland Association of Indigenous Construction Consultants
SAICE	South African Institution of Civil Engineering
SAICE-PDP	SAICE Professional Development and Projects
SANRAL	South African National Roads Agency Limited
SAPP	Southern Africa Power Pool
SAQA	South African Qualifications Authority
SCADA	Supervisory Control and Data Acquisition
SCDP	Secondary Centres Development Programme
SCTP	Société Congolaise des Transports et Ports (National Transport & Ports Company)
SDGs	Sustainable Development Goals
SEAP	Structured Engineers Apprenticeship Programme
SETAs	Sector Education Training Authorities
SEZ	Special Economic Zone
SHHA	Self Help Housing Agency
SIDS	Small Island Developing State
SIPs	Strategic Integrated Projects
SIT	Seychelles Institute of Technology
SKA	Square Kilometre Array
SLA	Seychelles Licensing Authority
SME	Small and Medium Enterprise
SMMEs	Small, Medium and Micro-sized Enterprises
SNCC	Société Nationale des Chemins de Fer du Congo
SNEL	Société Nationale d'Électricité (National Electricity Company, DRC)
SQA	Seychelles Qualification Authority
SSDS	Seychelles Sustainable Development Strategy
SSEF	Stratégie Sectorielle de l'Education et de la Formation (Sector Strategy for Education and Training)
STEM	Science, Technology, Engineering and Mathematics
SWC	Soccer World Cup
TAAG	Transportes Aereos de Angola
TANESCO	Tanzania Electric Supply Company Limited
TANROADS	Tanzania National Roads Agency

TAZARA	Tanzania Zambia Railway Authority
TB	Tuberculosis
TBD	To be determined
TCCA	Technical Committee on Certification and Accreditation
TCU	Tanzania Commission for Universities
TDM	Telecomunicações de Moçambique
TDV	Tanzanian Development Vision
TEC	Tertiary Education Commission
TNF	SADC Trade Negotiating Forum
TEU	Twenty-foot Equivalent Unit
TEVETA	Technical Education, Vocational and Entrepreneurship Training Authority
TNPA	Transnet National Ports Authority
TRC	Tanzania Rail Corporation
TVET	Technical and Vocational Education and Training
TVETA	Technical and Vocational Education and Training Authority
UAN	Universidade Agostinho Neto
UB	University of Botswana
UNAM	University of Namibia
UNESCO	United Nations Educational, Scientific and Cultural Organization
UNESWA	University of Eswatini
UNIDO	United National Industrial Development Organization
UNISA	University of South Africa
UoM	University of Mauritius
UoT	University of Technology
UPC	Abu Dhabi’s Urban Planning Council
USA	United States of America
USAID	United States Agency for International Development
UTM	University of Technology
UZ	University of Zimbabwe
VAs	Voluntary Associations
WACS	West African Cable System
WASCO	Water and Sewerage Company
WASH	Water, Sanitation and Hygiene
WFEO	World Federation of Engineering Organisations
WHO	World Health Organization
WMA	Wastewater Management Authority
WomEng	Women in Engineering
WSS	Water Supply and Sanitation
WUC	Water Utilities Corporation
YEP	Youth Employment Programme
ZACE	Zimbabwe Association of Consulting Engineers
ZAQA	Zambia Qualifications Authority
ZDA	Zambia Development Agency
ZEPARU	Zimbabwe Economic Policy Analysis Research Unit
ZESA	Zimbabwe Electricity Supply Authority
ZESCO	Zambia Electricity Supply Corporation
ZIE	Zimbabwe Institution of Engineers
ZINARA	Zimbabwe National Roads Administration
ZINWA	Zimbabwe National Water Authority
ZPC	Zimbabwe Power Company

Executive Summary

In 2015, African nations adopted Agenda 2063, which is a strategic framework for the socio-economic transformation of the continent over the next 50 years. Its builds on and seeks to accelerate the implementation of past and existing continental initiatives for growth and sustainable development. In the same year, the Sustainable Development Goals (SDGs), which replaced the Millennium Development Goals (MDGs), were launched.

SADC PLANS

In response to Agenda 2063, SADC countries have developed a suite of Vision documents and Action Plans for achieving SDG targets, and have adopted the SADC Industrialisation Strategy (2015–2063). The strategy has three pillars: industrialisation as the driver for economic and technological transformation; competitiveness as an active process to move from comparative advantage to competitive advantage; and regional integration. These are the context for industrial development and economic prosperity.

Countries have recognised, however, that many of the goals cannot be achieved without developing economic infrastructure such as roads, rail, ports, airports, water and energy supplies, and telecommunication networks. Regarding regional integration, corridors are key to maximise trade opportunities. The Industrialisation Strategy identifies the lack of adequate infrastructure and of skills and capacities in science, technology, engineering and mathematics (STEM) as among the binding constraints for industrial development.

To this end, the SADC Ministers of Science and Technology have endorsed an *Engineering Numbers and Needs Study* to gain a better understanding of the actual numbers of engineers, technologists and technicians in the region and the needs of Member States. This will allow for better planning and implementation of infrastructure programmes and ensure that there will be sufficient capacity for industrialisation. The outcome of the study is intended to offer input towards key SADC policies such as the Protocol on Education and Training, and the Protocol on Science, Technology and Innovation.

THE NEED FOR ENGINEERS

Engineering skills are required not only in manufacturing, but in all engineering sectors that contribute to the GDP. Figure 1 shows the sector contributions per country.

THE ENGINEERING SECTORS

The main engineering sectors are briefly outlined below. It is recognised that engineering skills are used in many other sectors, but to a far smaller extent. The use of and demand for engineering skills in the following sectors were examined in detail:

- **Agriculture,** which covers crops and animal production, forestry, fishing and aquaculture, water resource management, agricultural support and post-harvest activities.
- **Mining and quarrying,** which covers the mining of coal, ores, precious stones, crude petroleum and natural gas, stone, sand and clay. This could be underground, open pit, offshore or in alluvial sands.
- **Manufacturing,** which covers many industries, grouped as follows:
  - Food, beverages and tobacco products
  - Textiles, clothing and leather
  - Timber, pulp, paper and packaging
  - Plastics, chemicals and other non-metallic mineral products

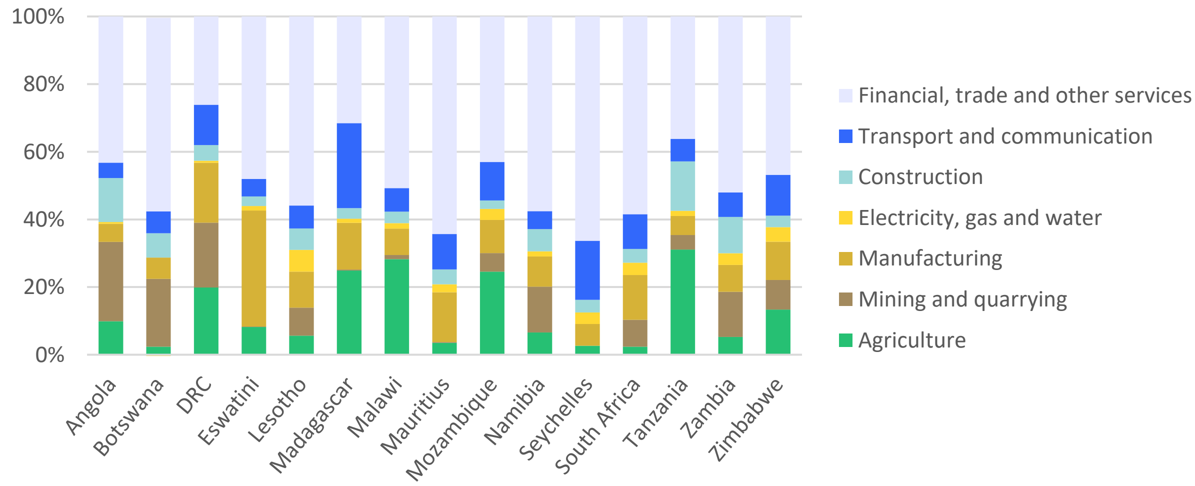


Figure 1: Percentage contribution to the GDP per sector
(Graphic presentation of Table 3)

- Pharmaceuticals
- Computer, electronic and optical products, and electrical equipment
- Metal industries, machinery and equipment.

- **Electricity, gas and water,** which covers a range of engineering sectors, including:
  - Electricity, gas, steam and air-conditioning
  - Water collection, treatment and supply, utilising water networks and stand-alone systems
  - Waste collection through sewage networks and stand-alone systems, treatment, disposal activities, materials recovery and other waste management services.
- **Construction,** which covers buildings and civil engineering works including public services such as transportation, communication, water and energy. Construction may cover new work, maintenance, additions and alterations, and the erection of temporary structures.
- **Transport and communication,** which covers two large sectors as follows:
  - Transportation, including the provision of passenger or freight transport, by rail, pipeline, road, water or air, as well as terminal and parking facilities, cargo handling, storage, etc.
  - Telecommunication services, including the transmission of voice, data, text, sound and video.

THE ENGINEERING LIFE CYCLE

Developing infrastructure, products or processes is not a trivial exercise, but requires many steps to ensure that a cost-effective and sustainable solution is developed, utilised and maintained. Whether a road, a new mobile phone, a vehicle or a streamlined data processing system is being designed, it is necessary to investigate and identify the need; to carry out feasibility studies, planning and detailed design; and to document the final solution before execution can begin. Once the development is complete, ongoing use, optimisation and maintenance must be managed. When the asset has reached the end of its useful life, the process begins again when designing a replacement or an upgrade. This cycle requires the dedication of engineering teams.

Teams are made up of a range of occupations working at different levels, from elementary workers to engineers and planners. This study has examined the number and need for engineers, technologists (also known as incorporated engineers) and technicians in the following disciplines:

- Agricultural engineering
- Chemical engineering
- Civil engineering
- Electrical, electronic, systems and telecommunications engineering
- Industrial engineering
- Mechanical engineering
- Metallurgical engineering
- Mining engineering.

DEVELOPING AND HARNESSING ENGINEERING PROFESSIONALS

The engineering skills pipeline is shown in Figure 2. The requirements to succeed are as follows:

- **Schooling:** Demonstrate an aptitude for mathematics and science as required by each programme in tertiary education.
- **Theory:** Complete an accredited professional degree or diploma through a university, polytechnic, university of technology or college.

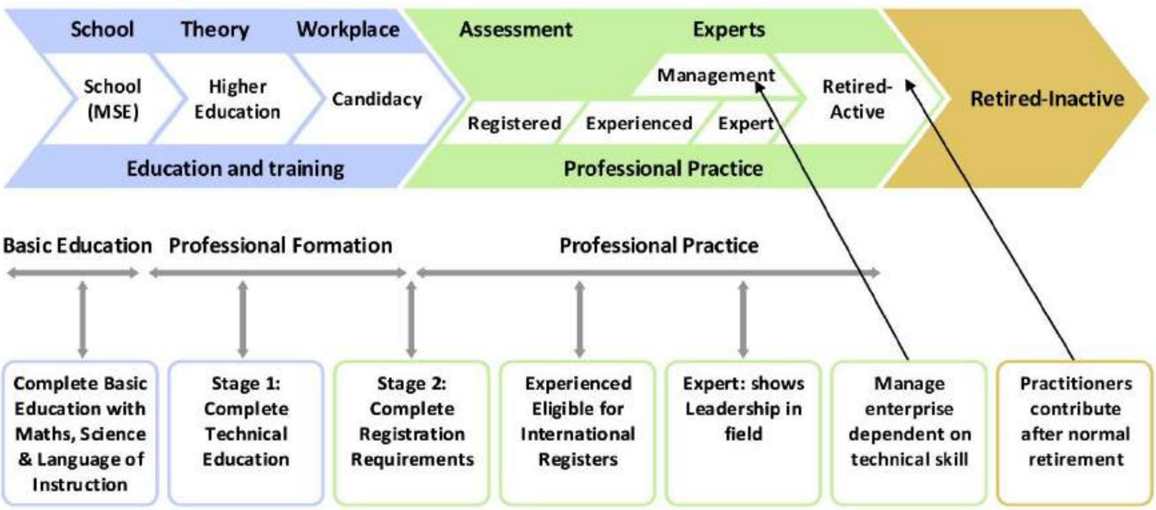


Figure 2: The engineering skills pipeline

- **Workplace**: Complete a workplace training phase, usually over three or more years, in a community of expert practice under supervision and mentorship.
- **Assessment:** Be assessed through an examination or peer review or both to determine whether the required level of competence has been achieved.
- **Registration:** Be awarded a designation commensurate with the person's education, training and experience.
- **Professional practice:** Work in a professional environment which values engineering professionals, offers them opportunities to develop as experts or to grow into management and leadership roles and affords them the opportunity to make technical and strategic decisions.
- **Institutional commitment:** Work in an environment where appropriate staff, systems, processes, support and necessary service providers are in place or may be appointed.
- **Investment:** Work in an environment where investment in planning, development, operations and maintenance of infrastructure, products, systems and/or processes takes place.

Recent graduates are only part of a substantial team of engineering practitioners, each with a different role to play. Conceptualising and designing mega projects require expertise, developed through years of experience, and the confidence to manage and lead change. When employers complain of not being able to find engineers, they are not referring to recent graduates, but rather to seasoned experts, able to tackle the most complex of challenges. The frenzy to increase the number of engineering graduates is misplaced and is only part of the process to develop engineering professionals for the future.

Each of the elements listed needs to be in place to allow young graduates to grow into strategic leaders. However, obstacles relating to many of these elements were identified during the study.

ENGINEERING STANDARDS

The ideal of developing a pool of engineers, technologists and technicians able to move around Member States, depending on the type and size of projects and expertise required, can only be realised if professionals are recognised from country to country.

The SADCQF

The SADC Qualifications Framework (SADCQF) has been set up, with levels and descriptors per level, for countries to classify their existing qualifications and adjust them to match the regional framework where required. Ten levels, commencing from school through to doctoral studies, have been decided upon. Technician, technologist and engineer qualifications appear to be at Levels 6, 7 and 8 respectively, although there is not consensus on the complexity required at Level 6, which must be addressed.

The IEA

The International Engineering Alliance (IEA) is a body that was first set up in 1989 to recognise the substantial equivalence of engineering degrees among countries. There were six signatories to the initial agreement, which was known as the Washington Accord. South Africa became the only African signatory in 1999. The Sydney and Dublin Accords followed, relating to engineering technologist and technician education respectively.

The cornerstone of the agreements has been the development of graduate attributes which must be achieved. Assessment looks at programme design, resources and the teaching and learning process, as well as student experiences and results.

The World Federation of Engineering Organisations (WFEO) was founded in 1968 under the auspices of UNESCO and represents more than 90 national engineering institutions. In essence, its role is to provide information and leadership to the engineering profession, society and governments on issues of concern to the public or the profession. As part of its commitment to supporting the delivery of the SDGs, WFEO has developed a 2030 Action Plan. One of the aims is to play a leading role in the '... *development of engineering capacity of appropriate recognised standards for sustainable development*'.

In December 2015, WFEO signed an agreement with the IEA, committing to use the IEA Accords as a single consistent global standard for engineering education. They also jointly committed to build the capacity of national accreditation bodies to facilitate their joining the Accords. The SADC region needs to make a similar commitment to using the Accords as the benchmark for enhancing the standards of engineering education in Member States.

The IEA has also developed mobility agreements to identify the competency standards and equivalent levels of practice expected of registered professionals. South Africa is also a signatory to these agreements. There is a need for registration standards in the balance of the SADC Member States to be aligned with these international standards, which are also endorsed by WFEO.

ELEMENTS OF THE STUDY

The study considers the long-term projects planned, the water, sanitation, electricity and other engineering-related SDG targets that must be achieved, the manufacturing industries to be developed or expanded, agricultural and mining developments and the types of engineering skill required to address these needs. Engineering disciplines and the role of the engineer, technologist and technician are outlined.

Recognising that skills are not static, but rather that there is a constant flow of skills, it was necessary to determine the current workforce, the demands, inflows from graduation and other sources, and outflows due to retirement, mortality, retrenchments, etc. Engagements with government departments, professional bodies and industry in each country yielded different insights. The information researched and sources from each country included:

- The supply of engineering graduates from tertiary education
- The engineering skills base per country and the mobility of engineering personnel
- Sectors in which engineering skills are required and the roles practitioners play
- Policies relating to engineering development and the regulation of engineering professionals
- Development and economic trends relating to each sector
- Projects planned per country and the region.

SECTOR STATUS QUO

Considering each sector, it is clear that there is an enormous amount of work for the engineering profession.

AGRICULTURE

In many countries, 50% or more of the population are subsistence farmers eking out an existence, living off the land. However, most countries only farm a small portion of the arable land and irrigate a small portion of the irrigable land. There are many opportunities for agricultural engineers to contribute to bringing about change, along with civil and mechanical engineers to address mechanisation, storage and post-harvest processes, among others. Increased irrigation, small-scale mechanisation, improved seeds, diversification of crops and access to markets are some of the many solutions that could be adopted, but all too often limited funding, infrastructure and support is a challenge.

MINING

The region is a treasure trove in terms of mineral wealth and there is still huge potential to increase mining output. However, poor infrastructure, high risks, national policies and political instability in many countries drive potential investors away.

MANUFACTURING

The potential to increase mineral beneficiation, secondary and tertiary processing, and develop agro-processing value chains and medium- and high-end technology is enormous and should contribute significantly to economic growth. However, in many cases, insufficient energy and water supplies, and inadequate transport networks and ports limit opportunities to expand markets and support manufacturing growth.

SOCIAL INFRASTRUCTURE

By 2015, few countries had achieved the MDGs. In some cases less than 50% of the population had access to safe drinking water, and significantly lower percentages had access to improved sanitation. Countries are working hard towards achieving the 2030 SDGs, but to develop from 10% or 20% in 2015 to 100% by 2030 will require enormous investment, engineering skills for the development of services, and, most importantly, maintenance teams to ensure that the new infrastructure does not deteriorate prematurely.

CORRIDORS AND TRANSPORT SERVICES

Substantial multi-modal corridors have been planned, including linking and developing roads and rail, and the use of waterways to improve the movement of resources and end products and ensure regional integration. In many instance roads and rail are not continuous and links must be developed, while in others refurbishing or substantial upgrading of aging infrastructure is necessary.

ICT

Considerable progress has been made with establishing modern telecommunication systems in each country. It is said that there are more mobile phones in Africa than taps. The need for electrical, electronic, software and telecommunications engineers continues to grow as the demand for extended connectivity, higher speeds and more mobile devices grows.

Executive Summary

Table 1: The Africa Infrastructure Development Index, 2018

COUNTRY	Ranking 2018	AIDI 2018	WSS	ICT	Electricity	Transport
Angola	29	19	40	12	6	2
Botswana	10	37	81	31	22	22
DRC	50	8	32	7	2	2
Eswatini	17	26	62	18	6	8
Lesotho	35	16	55	16	4	7
Madagascar	46	11	23	6	1	3
Malawi	25	21	66	7	2	5
Mauritius	5	77	98	59	40	38
Mozambique	44	12	27	11	12	2
Namibia	13	29	63	22	11	15
Seychelles	1	94	97	60	64	50
South Africa	4	79	80	77	75	22
Tanzania	43	13	28	10	2	3
Zambia	23	22	49	15	14	5
Zimbabwe	19	25	54	16	10	12

CONSTRUCTION

Construction is important in any country due to its ability to create jobs and develop skills. Massive projects have been identified, but without adequate funding they cannot go ahead. Where private sector funding needs to be raised, return on investment and the development of bankable projects become important. The inability to prepare such motivations has proved to be a stumbling block.

THE AFRICA INFRASTRUCTURE DEVELOPMENT INDEX

The Africa Infrastructure Development Index (AIDI) is a measure of infrastructure development. It considers the extent and condition of water supply and sanitation (collectively WSS), electricity, transport and ICT infrastructure and countries are ranked accordingly. It is measured out of 100. The Seychelles is ranked the highest, with an index of 94.3. The lowest rank of 54 is held by Somalia, with four SADC countries ranked between 43 and 50, indicating the extent of upgrading and development of both economic infrastructure and WSS required.

THE ENGINEERING SKILLS REQUIRED

When considering the huge developments planned, it is evident that experienced engineering professionals, rather than recent graduates, are required to conceptualise, motivate, plan, design and oversee the development of these projects. Mega projects are the ideal training ground for recent graduates so that they, too, will one day be able to play similar roles. The entire skills pipeline needs to be developed, but there appear to be blockages almost every step of the way.

THE CHALLENGES

From early childhood education to the selection of service providers, opportunities in the region are not conducive to growing tomorrow's engineering leaders or utilising current expertise.

THEORY

From early school days to graduating as engineers, there are many bottlenecks that require attention.

Schooling

In many countries, the percentage completing secondary education is limited. As a result, inadequate numbers with the aptitude to enter engineering studies are available. Where the numbers are higher, the quality of secondary education is not up to standard and as a result, students struggle with engineering studies and often drop out. The challenges in schools include poor facilities, lack of textbooks and, most importantly, the limited numbers of well-qualified teachers. Due to the sheer number of learners, national programmes harnessing technology need to be considered to compensate for the shortage of suitably qualified teachers.

To identify those with potential, significant career guidance and assessment programmes need to be mounted and funding raised, to attract those who excel in mathematics to enter engineering studies.

Tertiary education

Due to the ongoing lament from employers about the lack of engineering skills, countries have driven a large increase in tertiary education enrolment and have also encouraged private universities to open and expand offerings in the tertiary space.

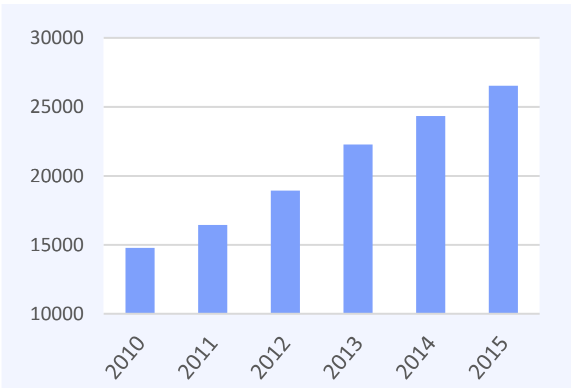


Figure 3: Engineering graduations in the SADC region

(Summary of Figure 23)

Gathering engineering graduation data covering several years in order to understand the trends proved almost impossible, but consideration of the data available from 2010 shows that the graduate numbers in the region have increased by almost 80% in the six years, as illustrated in Figure 3. Institutions advise that the numbers have continued to climb and some report that graduations in 2018 were more than double those of 2015.

The proliferation of tertiary education institutions offering engineering qualifications and the dramatic increase in the numbers studying at existing institutions has had many unintended consequences, including inadequate resourcing, a critical shortage of academics, poor quality of graduates and the production of many more graduates than the industry can absorb. Investment should rather be made in strengthening the established institutions to produce the desired calibre of graduates.

The alignment of qualifications requires attention. The content, degree of problem-solving and complexity vary from country to country and this will restrict the mobility of graduates and later professionals in the region, unless graduate attributes are aligned in time.

Accreditation processes also vary significantly in the region. A subcommittee needs to be set up under the Technical Committee on Certification and Accreditation (TCCA) to decide on levels, outcomes and accreditation regimes, and to develop a 10- to 15-year plan to ensure that institutions in the region work towards offering equivalent qualifications.

GRADUATE TRAINING

The claims of engineering staff shortages over decades do not relate to the shortage of graduates and the need to open more universities, but rather to the shortage of experienced personnel. This has come about due to the demise of the formal training programmes that were in place in large structures before outsourcing and unbundling took place. The move from permanent posts to contract appointments has also been a contributing factor.

Historically, it was the public sector that planned, designed, developed, operated and maintained infrastructure, managed and maintained fleets, and developed and managed their own significant systems. Public sector structures were therefore fertile training grounds for recent graduates, and staff who remained in the public sector, progressed through the ranks, developing institutional knowledge critical for making strategic decisions. Most engineers reaching retirement at present started their careers in the public sector.

Most of the meaningful work on which graduates can be trained today is in the private sector, but companies cannot afford to train large numbers when having to compete for business and tender at rock-bottom prices. Linking graduates to major public sector construction or manufacturing projects for training is also proving to be a problem as often international companies are appointed who are averse to employing or training local personnel and their staff do not always speak the local language.

Large national programmes need to be reinstituted to develop graduates into competent engineering practitioners so that countries reap the benefit of the investment made in undergraduate studies. A team composed of organisations which have successfully rolled out graduate training programmes should be put in place to design a regional model and suggest funding options and terms and conditions.

PROFESSIONAL REGISTRATION

The requirements for professional registration vary from country to country, and in some countries, there is no requirement for engineering practitioners to be registered at all. Without a recognised measure of competence, mobility in the region will be limited.

An additional subcommittee under the TCCA composed of registering bodies, potential registering bodies, the Southern African Federation of Engineering Organisations (SAFEO) and advisers from the IEA when required, should be set up to interrogate all Acts, establish best practice, and ensure that all countries adopt one set of outcomes per category and similar assessment processes.

DEVELOPING TOMORROW’S LEADERS

Returning to Figure 2, it can be seen that the end of the candidacy (graduate-in-training) phase is only the beginning of the professional’s career. Being assigned increasingly complex work and more responsibility, and continuing to develop through post-graduate or management studies or ongoing research are some of the many continuing professional development (CPD) activities necessary to become recognised specialists and/or engineering leaders. All too often, after the graduate phase, there is no further development and staff are assigned routine tasks year in and year out. Unless young professionals work alongside experts and are challenged and encouraged to develop, countries will continue to lament the shortage of engineers, as inexperienced staff will not meet their requirements.

Executive Summary

There is a fixation about not using foreign expertise or experienced practitioners from minority groups, and all too often recent graduates are paired with such experts and are expected to take over in a very short period. Without adequate meaningful post-graduate experience, young graduates are not equipped to comprehend the complexity of activities carried out by experts. Rather, mid-career practitioners with experience in the same field as that of expert practitioners should be selected as understudies and should be groomed to take over from experts in time.

THE PUBLIC SECTOR

Four of the six GDP contributors studied rely heavily on government spending, while the success of manufacturing and mining depends on government support and the policies in place. There are several challenges impacting successful development.

Engineering professionals

The numbers employed in the public sector are dwindling because salaries are low and conditions are not conducive to technical decision-making. In some countries, there has been a moratorium on employment in the public sector, while in others, the requirement for appointing only engineers who are professionally registered means that juniors cannot be appointed and developed through the ranks.

Technical expertise is required for long-term planning, overseeing service providers and managing operations and maintenance. Without technical structures and the requisite skills, the quality of the infrastructure developed is often problematic, and this infrastructure is not maintained, leading to premature failure. Structures, responsibilities, packages and training regimes must be revisited.

Policies

Although international service providers may have the skills and resources for large or complex projects, appointing foreign consultants and contractors as a matter of course should not be an ongoing phenomenon. Many projects, such as standard school structures, community halls and the like are well within the abilities of local companies.

As part of large projects, small contractors must be trained and where international service providers are appointed, local skills, materials and equipment must be used. In addition, designs, drawings and operating instructions must be made available in the official language of the country and must be checked and approved to ensure that they satisfy local needs.

As with professional registration, the categorisation of contractors varies throughout the region. In some countries, contractors need only apply for a licence, while in others they are categorised by skills, capital, equipment and past projects and may only be awarded contracts within their range of experience.

The SADC Trade Negotiating Forum (TNF) is focused on the liberalisation of the construction, energy and tourism sectors. Before relaxations can be agreed in terms of construction, it will be necessary to agree on a common approach when appointing both regional and international contractors. A threshold must be set below which only local contractors may be appointed in order to support contractor development and local job creation.

Similarly, the Industrial Development Forum should consider criteria to be included in offset agreements with manufacturers wishing to invest in Member States. These should include the development of small manufacturing companies to supply components, and the use and training of local skills including engineering professionals. They should also use local materials and equipment where available.

Many other policies also require review, to attract rather than deter investors, but they must include job creation and the development of local capacity and content.

Investment

There are many areas which require increased investment before it will be practical to increase engineering capacity. These include investment in:

- Expanding economic and social infrastructure
- Ongoing operations and maintenance
- Agricultural and manufacturing development
- Developing sustainable communities.

NUMBERS AND NEEDS

Combining engineering workforce estimates and registration data from each country suggests that there are almost 230 000 engineering practitioners in the region, just under 21% of whom are professionally registered as shown in Table 2. It should be noted that registration is in place in only 12 SADC countries, and in several countries only one or two of the three categories shown are eligible for registration.

The number graduating in 2015 represented just over 11% of the workforce, which is a large number to absorb in the absence of meaningful work. Anecdotally the graduation numbers have increased

Table 2: Estimated engineering workforce, registration, graduation and gender statistics for the region

NUMBER / CATEGORY	TOTAL IN THE WORKFORCE	REGISTERED		GRADUATES		GRADUATES AS A % OF THE WORKFORCE
		REGISTERED	% REGISTERED	IN 2015*	% FEMALE	
Engineers	114 579	34 722	30%	9 875	22.0%	9%
Technologists and technicians**	114 281	12 746	11%	15 607	24.7%	14%
TOTAL	**228 860**	**47 468**	**21%**	**25 482**	**23.7%**	**11%**

* Totals are understated as graduation data from some countries is incomplete – see Figure 23
** Technologist and technician categories are not recognised in all countries – see Table 24

significantly in several countries since 2015, contributing to the increasing pool of unemployed graduates.

The number of engineers is approximately 115 000, which is orders of magnitude lower than the numbers suggested by the OECD.

The temptation is to train many engineers in the hope that they will change the fortunes of the country. However, the **numbers** required are dictated by the extent of the infrastructure, the levels of service offered and the level of sophistication of manufacturing, among other factors. If infrastructure is limited as per the AIDI ranking, then there will be little work for engineering practitioners. If the levels of service are basic, then the complexity of engineering work and the numbers required will be low. If manufacturing is limited to low-tech food processing, the demand for engineering skills will be lower than for high-tech processes. If policies do not attract investors and development is limited, there will be little demand for additional engineering skills. Countries need to examine their plans and purposefully develop skills for the sectors identified.

Industrialisation aims to accelerate growth, create employment and improve living conditions. Skills must therefore be developed as part of the process. Furthermore, construction has long been recognised for its job creation potential, but must also be used to develop the **large number** of unemployed engineering graduates and apprentices, small contractors, subcontractors, suppliers and emerging manufacturers. The region needs to agree on rolling out infrastructure projects and investing in industrialisation, linked with localisation policies, if job creation and poverty alleviation is to succeed.

Of the many trends that have emerged, the most important areas which **need** attention are:

- Addressing poor schooling
- Addressing the proliferation of tertiary institutions offering inferior or unaccredited engineering qualifications
- Developing graduates and specialists
- Addressing the inconsistencies in professional and contractor registration
- Limiting the free rein given to international service providers
- Implementing policies which are investor friendly
- Investing in agricultural, rural, infrastructure and industrial development
- Rebuilding experienced engineering capacity with appropriate authority to plan and make technical decisions in public sector structures.

RECOMMENDATIONS

There are many areas which require attention to build capacity per country – these are detailed in each country report.

At a regional level, there are several areas in which harmonisation and collaboration are essential to ensure quality service delivery and capacity development. These are detailed in Chapters 7 to 12 and recommendations are summarised below.

School support

The enrolment in, and quality of, primary and secondary education needs to be improved. Many elements, including the number of qualified teachers, teaching methods and career guidance, require attention. Consideration needs to be given to harnessing technology and the 'flipped classroom' approach to reach and teach the large numbers currently excluded from quality education.

Rationalisation of tertiary education

The number of tertiary institutions, the number of students being enrolled, and the shortages of academics and appropriate resources need to be addressed.

Alignment and accreditation of qualifications

Alignment of qualifications and development of accreditation standards are important for mobility in the region. A subcommittee under the TCCA must be set up to debate graduate attributes for each level of qualification. A programme must be developed with milestones for institutions to work towards to upgrade curricula, develop capacity and acquire the resources required to achieve the requisite graduate attributes over time.

Graduate and professional training

To address the ever-growing challenge of unemployed graduates a regional approach to developing graduates must be established and adopted. A committee composed of employers and professional bodies who have been successful with graduate training should be formed to develop guidelines and national funding and support is essential. Professional development beyond registration must also be provided.

Alignment of registration processes

Unless there is a uniform measure for assessing the competence of engineering professionals, mobility in the region will be restricted. A committee under the TCCA representing all registering bodies needs to be formed to agree on the outcomes to be measured when assessing applicants for registration, the assessment methods, and how to handle foreign applications.

Repopulation of public sector structures

A concerted effort is required to repopulate public sector structures with competent engineering professionals, with decision-making authority, and to set up systems for developing future generations.

Alignment of service provider conditions

The TNF needs to form a subcommittee to look at construction board or council Acts and agree on standards throughout the region for classifying contractors and the type of work they may be appointed to carry out. Harmonisation of training requirements and the use of local conditions of contract, local labour, materials and equipment should also be considered, and regional resolve will be required to enforce these conditions.

Localisation

The Industrial Development Forum to share knowledge and experiences on setting up offset agreements. Agreements should include not only the use of local labour, plant, equipment and developing local manufacturers but should include the training of engineering professionals.

Investment

Without investment in infrastructure and maintenance, growth cannot take place. Major projects must be prioritised, and the funds raised, but care must be taken that funds are largely spent on local staff, materials and equipment. Care must also be taken that appropriate solutions are selected which satisfy local conditions, offer value for money and address the needs of as many as possible.

Agricultural engineering solutions

Regional solutions need to be researched and shared to support countries with innovative ideas on how to assist smallholders to become more productive and contribute towards national food security.

Rural development

Infrastructure development has largely been focused in urban areas and industrial centres. Rural development programmes and support for rural communities is essential to grow rural economies and encourage de-urbanisation.

Data collection

Centralised reporting systems need to be considered for compiling reliable and detailed labour, education, professional and service provider information for better planning.

Industry liaison

To give input on the many engineering challenges, it is suggested that a *National Engineering Advisory Team* composed of experts nominated by associations, institutions and engineering boards in each country, be constituted per country to engage with government as and when considered necessary. The team should include academics and practitioners covering all disciplines from the private and the public sectors.

Part 1
Context

PART CONTENTS

Part I outlines the SADC development plans and rationale for the study. The need for engineering practitioners, how they are trained and standards the region should aspire to are outlined. The continuous flow of skills and the scope and performance of each engineering sector per country is considered to set the scene for understanding the assessments carried out, findings and recommendations. The research approach is outlined in Chapter 5.

The remaining parts are as follows:

Part II which looks at the overall findings for each stage of the engineering skills development pipeline and includes regional recommendations.

Part III which includes detailed reports and recommendations per country.

Chapter 1

SADC Plans

There has never been greater pressure on nations to improve economic growth to address the burgeoning challenges of poverty, food security, unemployment and climate change. Attendant with these is the need to improve the opportunities for health care and education.

AGENDA 2063 AND AGENDA 2030

Recognising these challenges, in 2015 African nations adopted Agenda 2063, which is a strategic framework for the socio-economic transformation of the continent over the next 50 years. Its builds on and seeks to accelerate the implementation of past and existing continental initiatives for growth and sustainable development.

The guiding vision for Agenda 2063 is the African Union (AU) Vision of *'An integrated, prosperous and peaceful Africa, driven by its own citizens and representing a dynamic force in the international arena'*.

The year 2015 was a watershed year for Africa, as not only was Agenda 2063 adopted, but the Sustainable Development Goals (SDGs), which replaced the Millennium Development Goals, were launched. The SDGs cover a range of social and economic development issues to end poverty, protect the planet and ensure prosperity for all. In more detail they address poverty, hunger, health, education, climate change, gender equality, water, sanitation, energy, urbanisation, environmental concerns and social justice.

The SDGs have become known as Agenda 2030 or *Transforming our World: the 2030 Agenda for Sustainable Development*. Each goal has specific targets to be achieved over the period to 2030.

Considering many of the initiatives on which Agenda 2063 was built, such as the Programme for Infrastructural Development in Africa (PIDA), the Comprehensive Africa Agricultural Development Programme (CAADP) and the need to address the SDGs, many regional and national plans and programmes have been developed. The Southern African Development Community (SADC) is one such regional body that has responded to both Agendas.

SADC DEVELOPMENT

The SADC region is blessed with abundant and diverse natural resources, but countries continue to export unprocessed goods, earning a fraction of the potential value of the products, and hunger and poverty persist. Agenda 2063 aims to optimise the use of Africa's resources for the benefit of the continent's people. In response to Agenda 2063, SADC countries have developed a suite of Vision documents and Action Plans for achieving SDG targets, and have adopted the **SADC Industrialisation Strategy (2015–2063)**.

The strategy is anchored on three pillars: industrialisation as the driver for economic and technological transformation; competitiveness as an active process to move from comparative advantage to competitive advantage; and regional integration. These are the context for industrial development and economic prosperity.

The strategic goals embodied in the industrialisation strategy include an increase in manufacturing and exports, a move to manufacturing more medium- and high-technology products, and doubling industrial employment. Industrial employment is expected to make up 40% of total employment by 2030. The growth areas identified include agro-processing, mineral beneficiation and related mining processes, pharmaceuticals, consumer goods, capital goods and services.

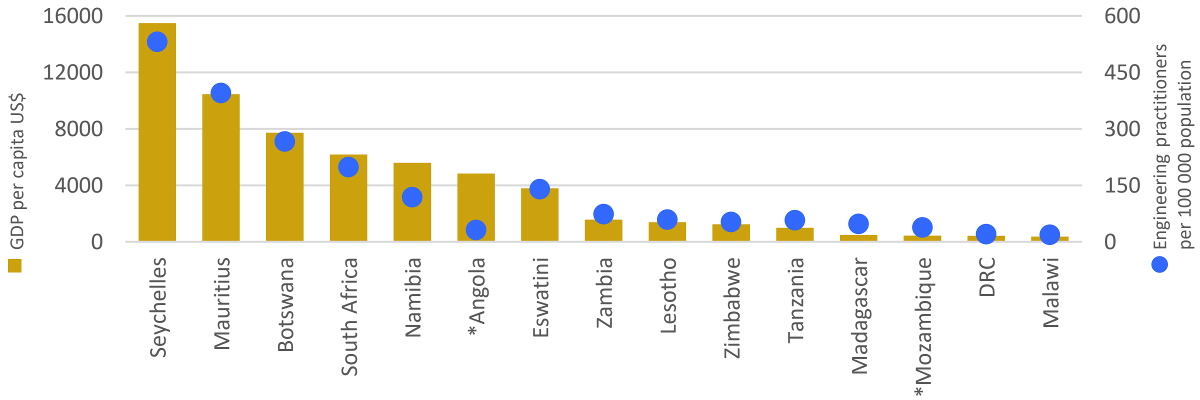


Figure 4: GDP per capita 2016 vs engineering practitioners per 100 000 population
(Engineers only)*

Due to poverty levels and high unemployment in rural areas, there is a clear understanding that there is unlikely to be an industrial revolution in SADC without improved agricultural productivity, creating rural agro-processing clusters and making agro-processing careers attractive to the youth. To this end, in 2003 CAADP was established by the Assembly of the AU with the aim of raising agricultural productivity by at least 6% per year and increasing public investment in agriculture to 10% of national budgets per year.

Countries have recognised, however, that many of the goals cannot be achieved without developing economic infrastructure such as roads, rail, ports, airports, water and energy supplies, and telecommunication networks. Regarding regional integration, corridors are key to maximise trade opportunities. Many strategies and plans have been developed to support continental and regional development, the most significant of which are:

- **The Regional Indicative Strategic Development Plan (RISDP)** which calls on Member States to integrate their markets and work towards achieving peace, stability and wealth. In particular, it focuses on liberalisation, regional integration, food security and social and human development, and recognises the underlying need for infrastructure.
- **The Programme for Infrastructure Development in Africa (PIDA)** which promotes regional economic integration by building infrastructure which allows the flow of goods and associated trade between countries. Infrastructure investments in energy, transport, ICT and trans-boundary water are aimed at increased connectivity. Thirty-four PIDA projects were planned for the SADC region.
- **The Regional Infrastructure Development Master Plan (RIDMP)** which guides the development of key infrastructure in the region and acts as a framework for planning and cooperation with development partners and the private sector. The master plan is being implemented over three five-year intervals – the first (2012–2017) considered the short-term needs, the second (2017–2022) the medium term and (2022–2027) the long term.

Engineering professionals are key to many of these aspirations and are thus required to play a significant role in changing the fortunes of SADC countries. It is essential however, that they are adequately educated, trained and their skills are utilised to the full to deliver innovative solutions to agricultural production, manufacturing and mining output, and engineering service delivery. Figure 4 shows the relationship between GDP per capita and the number of engineering practitioners per 100 000 population. While it is tempting to suggest that more engineers will increase the GDP, this is not the case. Only when there is investment in infrastructure, manufacturing and mining can such skills be utilised and developed.

Nine of the 17 SDGs are reliant on engineering skills and several others require engineering facilities to be in place, such as health care and education infrastructure. Industrialisation, which will play a major role in transforming economies, can also not take place without adequate engineering capacity. The development and harmonisation of engineering skills and standards will be key to the implementation of both Agenda 2063 and Agenda 2030 and to the industrialisation strategy.

SADC NUMBERS AND NEEDS STUDY

To this end, the SADC Ministers of Science and Technology endorsed the *Engineering Numbers and Needs Study* to achieve a better understanding of the actual numbers of engineers, technologists and technicians in the SADC countries and the needs of SADC Member States in order to allow for better planning for the attainment of sustainable development in the region.

The overall objective of the study is to gain a better understanding of engineering numbers to determine whether there is adequate capacity for planning and implementing infrastructure programmes, and for enhancing output and productivity in the agricultural, mining and manufacturing sectors to support the SADC Industrialisation Strategy (2015–2063).

The Strategy identifies lack of adequate infrastructure and capacities in science, technology, engineering and mathematics (STEM) as among the binding constraints for industrial development. The outcomes of the study will serve as input towards the implementation of key SADC policies and frameworks such as the RIDMP, the Protocol on Education and Training, and the Protocol on Science, Technology and Innovation.

ECONOMIC GROWTH AND GDP

Economic growth is seen as the enabler for job creation and the reduction of poverty. Year-on-year changes in the GDP are considered to determine whether economies are growing or shrinking and to make regional and international comparisons. The GDP is a measure of the market value of all final goods and services produced. Given population differences and degrees of industrialisation, a more useful measure for comparing the success of nations is to use the ratio of GDP to the total population, termed the 'GDP per capita'.

It is envisioned that by 2063, the SADC region will be fully transformed and will be an important player in the continental and global landscape, premised on the three growth phases:

1. **Phase I (2015–2020)** which constitutes a period of active industrial and infrastructure development, and market and services integration with industrialisation. During this phase, SADC countries should target income growth of about 6% per year to achieve a GDP per capita of US$2 000.
2. **Phase II (2021–2050)** which will focus on diversification and enhancement of productivity and competitiveness. By the end of this period, SADC aims to achieve GDP per capita of US$9 000 and a growth rate of 8% per year from 2020 onwards.
3. **Phase III (2051–2063)** during which SADC economies should move into the innovation-driven stage, characterised by advanced technologies and increased business sophistication. To achieve that status, GDP per capita needs to rise to US$17 000 by 2063, with an income growth of about 5% per year.

Although most SADC countries experienced high growth in the early 2000s, growth has since slowed significantly, as shown in Figure 5. This can be attributed to lack of decisive leadership, reduced international demand and the related reduction in commodity prices, policy changes, climate change and corruption, among others.

THE INFLUENCE OF POLICY CHANGES

Policy changes have been particularly devastating. The models for redistribution of wealth and indigenisation, although noble in ideals, did not consider the possible consequences of business failures and that the very people the new policies

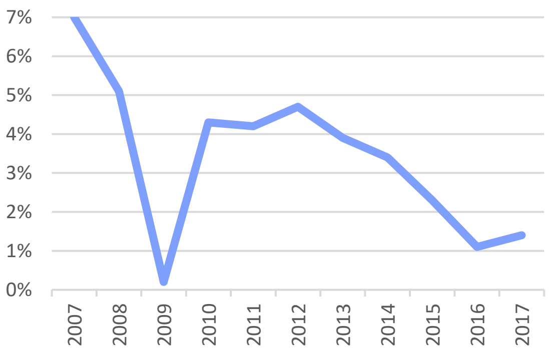


Figure 5: Percentage growth in GDP in SADC

were trying to serve would find themselves worse off due to job losses and reductions in food production, among other unintended consequences.

The nationalisation of mines or individual commercial farming operations, expropriation of land, and the indigenisation of many organisations in the interests of sharing wealth have generally resulted in loss of expertise and operational capacity, with an associated drop in production, lack of maintenance and the exit of investors.

An analysis of the 15 SADC countries at the time of their independence shows that several, such as Malawi, Lesotho, Madagascar, Mozambique, Botswana, Mauritius and the Seychelles, had limited resources and were among the poorest countries in the world. Most of the balance were prosperous and world players in one or more sectors or product lines, mostly in the mining sector and/or agriculture. These included South Africa, Namibia, Angola, Zambia and the DRC, with Zimbabwe being known as the *'Bread Basket of the World'* at the time of independence. Inappropriate policies, corruption, civil war and political instability have had a devastating effect. For instance, in the 1960s, before independence, the DRC was the second strongest economy in Africa, after South Africa. Today, it has one of the lowest GDPs per capita in the world. Zimbabwe went from being a strong economy with thriving manufacturing, mining and agricultural sectors, and a net exporter of food, to being a net importer of food and finding itself without currency in the second half of 2018.

Zambia at independence was among the richest countries in sub-Saharan Africa with copper being a substantial foreign currency earner, but after nationalisation, the lack of re-investment in those industries led to low production and inefficiency, with a devastating effect on the economy. Returning to privatisation brought the much-needed capital, and improved economic conditions. Tanzania followed a similar pattern and had to re-privatise to raise funding to cover rising debt.

Namibia's strong economy was based on fish, meat processing, karakul, base metals and diamonds. Overfishing has reduced that particular market and debt has mounted due to international funders carrying out the large infrastructure developments without harnessing local labour or resources. Namibia's debt deficit had reached 40% of the GDP by mid-2018.

Lesotho and Botswana's fortunes changed with the discovery of diamonds in the 1970s, which has led to substantial growth. More recently, the discovery of gas and oil in Tanzania and Mozambique, and of cobalt and ilmenite in Madagascar bodes well for these economies. Sadly, much of the benefit of the increased income is not realised by the general population, but by leaders and the foreign governments who have offered the capital to get new mining ventures off the ground and develop the associated infrastructure.

To their credit, Mauritius and the Seychelles have transformed their economies by developing their tourist industries and associated manufacturing industries, such as the food, beverage, herbs, handcrafts and textiles industries, to support tourism.

As a result of the changes in policies and approaches, today only three SADC countries appear in the top 10 list of economies in Africa – with South Africa holding second position, Angola the fifth and Tanzania the tenth position in 2017, according to the IMF. In terms of GDP per capita, only four countries are rated in the top 100 worldwide, namely the Seychelles at number 53, Mauritius 68, Botswana 87 and South Africa 96. The DRC, Madagascar, Mozambique and Malawi were at positions 189, 191, 193 and 195 out of 197 countries whose GDP per capita were determined and published by the World Bank.

Returning to Agenda 2063, which calls for *'An integrated, prosperous and peaceful Africa, driven by its own citizens and representing a dynamic force in the international arena'*, it is time for those with potential to claw their way back to prosperity. This cannot happen without enabling policies, strong, people-centred leadership and substantial private sector investment.

SKILLS DEVELOPMENT AND INTEGRATED PLANNING

One of the biggest injustices of the colonial era was the lack of local skills development at higher levels. Africans were largely excluded from highly skilled and managerial positions. Furthermore, infrastructure was generally built to service exports, rather than to promote internal trade.

In attracting investors and accepting loans, stringent skills development targets must be put in place and managed. These should not be limited to providing bursaries for students, but should span the skills pipeline from schooling, through tertiary education and graduate training, all the way up to the development of managers, technical experts and internationally recognised specialists.

As discussed, the highest earning country per capita is the Seychelles, which relies largely on tourism, a service industry. This service relies on excellent infrastructure, transport and communications to attract tourists from all over the world. It is interesting to note that when comparing the number of engineers, technologists and technicians per 100 000 population, the Seychelles boasts the highest ratio as shown in Figure 4. The Seychelles also boasts the highest Africa Infrastructure Development Index (AIDI) in the SADC region.

Infrastructure development is thus key to economic growth and its development is the foundation on which local skills can be developed with the assistance of international expertise. As the depth of local skills grows, the reliance on international expertise should reduce. Skills transfer is, however, not a short-term process. It takes many years to develop a seasoned professional, as outlined in Chapter 3, *Developing Professionals*.

When sources of funding are being considered, internal sources should not be forgotten. Although it is not a popular concept, payment for services must become part of the national psyche. A significant percentage of those receiving services can afford to make some contribution, but payments are not enforced, and countries' coffers are drained. The African Development Bank (AfDB) reports that tax revenue collection in Africa is below the threshold of 25% of GDP considered necessary to scale up infrastructure spending.

Multi-disciplinary and regional planning are essential to ensure that countries do not compete for the same markets or skills and that the use of resources is optimised. Locally, departments should collaborate to optimise construction activities. For example, when contractors are appointed to implement rural electrification programmes, it would be more cost-effective if they addressed rural water and upgraded local facilities at the same time.

When changes in policy and the approach to development take place, only then will countries need to consider increasing the size of their engineering workforce. Engineering education and training forecasts in this study consider 2017 growth rates and those projected by the IMF for 2018 to 2023 and give an indication of the requirements should the Agenda 2063 growth targets be met.

Chapter 2

Need for engineers

Without good infrastructure and transport, economies cannot develop. John F. Kennedy is widely quoted as saying 'It is not our wealth that built our roads, but it is our roads that built our wealth'.

The African Development Bank has recognised that the 'High 5s' are crucial for accelerating Africa's economic transformation – these are:

- Light up and power Africa
- Feed Africa
- Industrialise Africa
- Integrate Africa
- Improve the quality of life for the people of Africa.

The overall objective of the Numbers and Needs Study is to gain a better understanding of the engineer, technologist and technician capacity in the region. Without such skills, better planning and implementation of infrastructure programmes to support the SADC Industrialisation Strategy cannot proceed. It is thus necessary to understand where engineers are employed and what disciplines are required.

THE ENGINEERING SECTORS

Contributions to the GDP come from several industries and sectors of the economy. Sectors range from primary industries such as agriculture, in which produce is grown and sold without any value addition, to tertiary industries such as the manufacturing of motor vehicles, or services such as financial services. A comprehensive set of activities has been defined against which to measure and report on economic activities, known as the *International Standard Industrial Classification (ISIC) of All Economic Activities. Revision 4* is the current revision in use. There are 99 activities listed under 21 headings.

In the SADC region, many of these have been grouped under the following headings for purposes of uniform reporting:

- Agriculture
- Mining and Quarrying
- Manufacturing
- Electricity, Gas and Water
- Construction
- Wholesale and Retail Trade, Restaurants and Hotels
- Transport and Communication
- Finance, Insurance, Real Estate and Business Activities
- General Government Services
- Other Services.

As countries industrialise, the growth in GDP becomes more dependent on the development of skills and associated services than on the use of labour, machinery and supply of products.

The first five sectors above, plus transport and communications, rely on the availability of engineering skills in one way or another to plan, design, operate, optimise or maintain infrastructure, systems or processes.

Table 3 shows the GDP contributions of all sectors, by value for each country for 2015, while Figure 6 shows the contribution to GDP per engineering sector for each country over a number of years.

Most countries have one or two sectors that are stronger than the others, and many of these are primary industries such as agriculture or mining. Only a few have any significant manufacturing contribution. Eswatini is one of the notable exceptions, having developed an impressive sugar manufacturing sector, based on the near-perfect conditions for growing sugar cane in the Lowveld. The growth of the manufacturing industry has in turn created more demand and many smallholders have been able to benefit, selling their cane to the sugar mills to augment production.

The Mauritian manufacturing sector also relies on sugar and the production of electronic goods, which was a strategic move to diversify. Lesotho's textile industry is the backbone of that country's manufacturing sector.

Manufacturing is, however, not the only solution for improved economic performance. Many countries in the region are net importers of basic foodstuffs, although soil and climate conditions are such that local production should be adequate to meet their needs. In these instances, improved techniques need to be introduced, which rely largely on scientific and engineering innovations and know-how.

Throughout the region, development is required in each of the engineering sectors, all of which require engineering skills. For a better understanding of the engineering opportunities and needs, the scope of each engineering sector is outlined in this chapter.

Table 3: % Contribution to GDP per sector, 2015

COUNTRY	ENGINEERING CONTRIBUTORS						% ENG	OTHER CONTRIBUTORS			
	Agriculture	Construction	Electricity, Gas & Water	Manufacturing	Mining & Quarrying	Transport & Communication	% contribution of engineering GDP to total	Finance, Real Estate, Business	General Government Services	Other Services	Wholesale & Retail Trade, etc.
Angola	9.9%	13.0%	0.5%	5.3%	23.5%	4.5%	**56.8%**	6.2%	11.3%	9.3%	16.4%
Botswana	2.4%	7.2%	-0.4%	6.3%	20.2%	6.5%	**42.3%**	16.3%	16.9%	6.6%	17.9%
DRC	19.9%	4.7%	0.6%	17.7%	19.1%	11.9%	**73.9%**	8.6%	5.9%	-	11.6%
Eswatini	8.2%	2.9%	1.3%	34.3%	0.2%	5.1%	**51.9%**	16.3%	7.1%	8.9%	15.7%
Lesotho	5.6%	6.3%	6.4%	10.6%	8.3%	6.8%	**44.1%**	14.4%	13.7%	12.6%	15.1%
Madagascar	24.9%	3.2%	1.2%	13.8%	0.2%	25.1%	**68.5%**	2.5%	7.2%	11.3%	10.6%
Malawi	28.3%	3.4%	1.6%	7.8%	1.2%	6.9%	**49.2%**	17.6%	2.6%	10.3%	20.3%
Mauritius	3.5%	4.4%	2.3%	14.7%	0.2%	10.4%	**35.7%**	25.6%	6.1%	14.1%	18.5%
Mozambique	24.6%	2.5%	3.3%	9.8%	5.5%	11.3%	**56.9%**	11.1%	17.3%	0.7%	14.0%
Namibia	6.6%	6.6%	1.5%	8.9%	13.5%	5.3%	**42.4%**	13.9%	12.3%	16.3%	15.0%
Seychelles	2.7%	3.7%	3.4%	6.4%	0.0%	17.5%	**33.7%**	30.5%	7.4%	5.5%	22.9%
South Africa	2.4%	4.0%	3.7%	13.2%	8.0%	10.3%	**41.5%**	20.6%	17.0%	5.9%	15.0%
Tanzania	31.1%	14.6%	1.5%	5.6%	4.3%	6.7%	**63.8%**	11.1%	6.9%	5.5%	12.6%
Zambia	5.3%	10.7%	3.5%	7.9%	13.4%	7.2%	**48.0%**	11.6%	4.7%	10.5%	25.3%
Zimbabwe	13.3%	3.4%	4.3%	11.3%	8.8%	12.1%	**53.2%**	13.4%	3.6%	13.8%	15.9%

AGRICULTURE, FORESTRY AND FISHING

This sector consists of the growing of crops, raising and breeding of livestock, the harvesting of timber and other plants, and fishing and hunting. Agro-processing, however, falls under manufacturing.

The SADC region, and indeed most of Africa, consists of large rural populations, the majority of whom are involved in subsistence agriculture. To improve their livelihoods, the opportunity to grow and sell crops is important. This may rely not only on irrigation (including dams, canals, wells and boreholes) and energy supplies, but also on adequate transport infrastructure to get their products to market. Also essential is post-harvest support, such as drying, storage, refrigeration, freezing and packing facilities, to ensure that harvested products do not spoil.

Several engineering disciplines are to be found working in this sector: from chemical engineering practitioners involved in agro-processing; civil engineering practitioners involved in the development of dams, irrigation systems, roads and structures; electrical engineering practitioners largely involved in renewable energy; mechanical engineering practitioners involved in mechanisation, refrigeration and the manufacture and supply of equipment. Agricultural engineering practitioners have a combination of the knowledge of all disciplines described, plus have had training in crop production, livestock, post-harvest processing and agricultural systems and processes to equip them to develop innovative technological solutions to increase production and improve productivity. Industrial engineers are also used to enhance systems and process flows in terms of planning, harvesting and processing.

MINING AND QUARRYING

This sector covers mining and quarrying, including the extraction of minerals occurring naturally as solids (coal and ores), liquids (petroleum) or gases (natural gas). Extraction can be achieved by different methods, such as underground or surface mining, well operation, seabed mining, etc. This sector includes supplementary activities aimed at preparing materials for use, such as crushing, grinding, cleaning, drying, sorting, concentrating ores, liquefaction of natural gas and agglomeration of solid fuels (see Figure 7). These operations are often carried out by the units that extracted the resource and/or others located nearby. However, the sector excludes the processing of the extracted materials, which is covered under *Manufacturing*.

Mining, civil, electrical and mechanical engineering practitioners are required initially to plan and construct, and later to maintain and optimise operations.

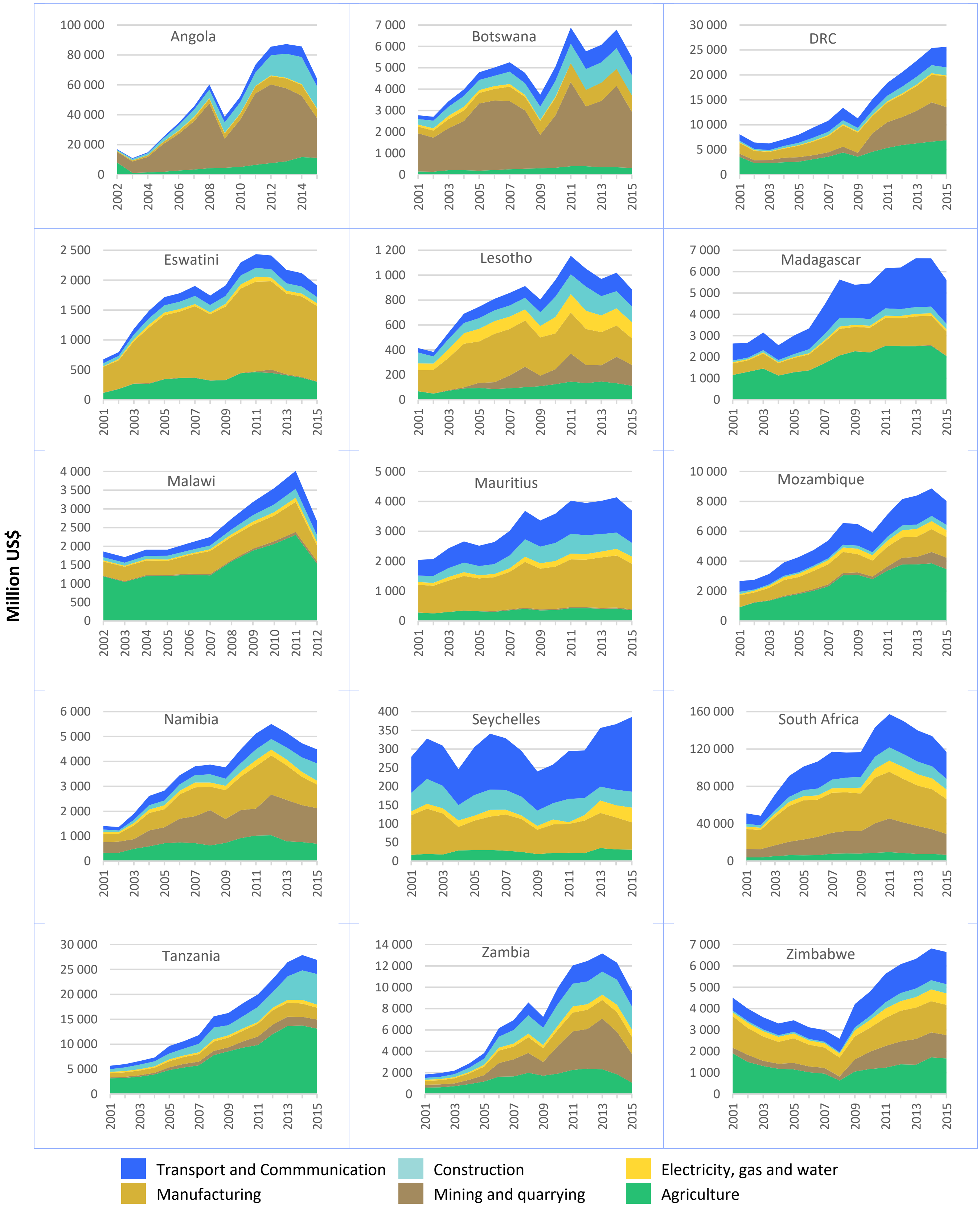


Figure 6: Engineering GDP per sector in SADC countries

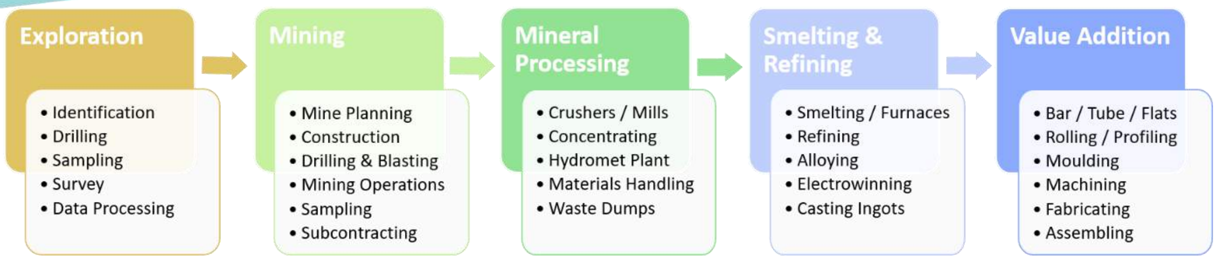


Figure 7: The mining and beneficiation process

MANUFACTURING

This sector covers 33 categories under ISIC which can be summarised as follows:

- Food products, beverages and tobacco products
- Textiles, clothing and leather goods
- Wood and wood products, paper, packaging, publishing and printing
- Furniture and other related manufacturing
- Petroleum, chemical products, rubber and plastic products
- Electrical equipment and electronics
- Machinery, motor vehicles, parts and accessories, and other transport equipment
- Glass and non-metallic mineral products
- Basic iron and steel, non-ferrous metal products, metal products and machinery
- Other.

Agro-processing

There has been considerable debate on the difference between agro-processing and manufacturing. Essentially, agro-processing is a subset of manufacturing which processes raw materials and intermediate products derived from the agricultural sector. ISIC categorises 11 divisions under agro-processing: food, beverages, paper and paper products, wood and wood products, textiles, wearing apparel, furniture, tobacco, rubber products, footwear, leather and leather products. Agro-processing minimises post-harvest losses of perishable produce, including fruit, vegetables, milk, meat and fish among others.

Secondary processing of farm produce is handled by many mills, such as flour, sugar and rice mills, etc. End products, such as cereals, baked and confectionary goods, processed foods and beverages, emerge after tertiary processing. Pickled, dried and frozen products also offer long shelf life. Given stringent health and safety requirements, the quality expected by consumers, and productivity demanded by shareholders, engineering skills are required to plan, oversee and optimise processes. Controlling feedstock, the quality of water, temperature and pressure, and minimising downtime are key elements which engineering practitioners must manage. Chemical engineers are important in this sector.

It is interesting to note that even those countries that claim not to have a manufacturing sector of any worth, all had at least one brewery and some plants producing international brands of carbonated drinks under licence, sweets and chocolates, all of which employed engineering practitioners.

The manufacture of tobacco products such as cigarettes, pipe and chewing tobacco, cigars and snuff is a substantial activity in several countries.

In terms of textiles and clothing, the US African Growth and Opportunity Act (AGOA) enacted to enhance market opportunities for sub-Saharan countries has resulted in growth in the textiles and garment sector, as goods imported from African countries by the USA are quota- and duty-free.

Over the years, the production of fabric has declined, with countries importing material from elsewhere in Africa and rather making clothing for export. Where cotton is still grown, ginning and weaving facilities require engineering skills.

Plants that manufacture pulp, paper and converted paper products are to be found throughout the region. The range of papers and packaging material has become an integral part of our daily lives. The list of paper products is extensive, from tissues and toilet paper to paper cups and plates, computer and copy paper, labels and envelopes, to name but a few. Packaging products include cardboard boxes, egg trays and other moulded pulp packaging products. There are many substantial manufacturers of paper and packaging materials which employ literally hundreds of engineers and technicians.

The manufacturing of wood products other than pulp also falls under this section. This includes the manufacture of plywood, veneers, wooden containers, flooring, trusses and prefabricated wooden buildings. Much of this work is carried out by artisans, but engineering skills are required for the design of roof trusses and buildings.

Need for engineers

The manufacture of wearing apparel, furniture and leather goods relates largely to handcrafts in the region, but the balance of production is generally the domain of large processing plants employing the full complement of engineering skills.

Petroleum, chemicals, rubber and plastic products

This industry includes the transformation of organic and inorganic raw materials by chemical processes into end-user products. A huge variety of products are covered under this heading, including motor fuels, oils, road surface materials, waxes, pharmaceuticals, fertilisers, plastics, rubber, paint, ink, gases and alcohol, to name but a few. Not only are chemical engineers required to design and optimise processes, but electrical, industrial and mechanical engineering skills are required to manage the range of complex equipment, pressure vessels and to maintain a controlled environment.

Other non-metallic mineral products

This category includes the production of glass, clay and refractory bricks, and cement and cement products, among others. The sector would generally require civil and mechanical engineering skills.

Mineral beneficiation

The manufacture of basic iron and steel entails secondary processing by the mining sector, while tertiary processing involves machinery, vehicles and parts. The last two stages in the mining value chain shown in Figure 7 fall under *Manufacturing*. Smelting, refining and fabrication add considerable value to the original product and the fabrication phase offers substantial employment opportunities.

Once again engineering skills are critical for planning, overseeing and optimising processes. In secondary processing, metallurgists play a key role in extraction, while it is mainly mechanical and electrical engineering practitioners who operate and maintain tertiary processes, along with industrial engineers, who have become increasingly important for optimising and streamlining processes.

Electrical equipment and electronics

This industry includes the manufacture of computers, computer peripherals, control and communications equipment, and similar products, as well as the manufacture of components. Production processes are characterised by the design and use of integrated circuits, and the application of highly specialised miniaturisation technologies. By and large this sector employs electronic and systems engineers.

Machinery, equipment, motor vehicles and other transport equipment

This sector includes the manufacture of machinery and equipment and their mechanical components. Machinery may be fixed, mobile or hand-held devices used for industrial, building, construction and agricultural purposes, for home use or in passenger or freight transport.

In terms of transport the range of motor vehicles, trailers, rolling stock, ships, boats, floating structures, aircraft and spacecraft, military vehicles, motorcycles, bicycles, parts and accessories are covered in this sector.

The sector employs mainly mechanical and electrical engineering practitioners.

Hi-tech versus low-tech

It is important to note the classification of various goods into low-tech, medium-tech and high-tech categories. Generally, agro-processing activities and the manufacture of furniture are low-tech, while basic rubber, plastics, metal and petroleum industries are considered to be medium-tech. The manufacture of chemical products, machinery, electrical goods, electronics, motor vehicles, parts, medical precision and optical instruments are considered high-tech. The latter would require higher numbers of engineering practitioners, and the job multipliers increase. 'Job multipliers' refers to the number of people engaged in downstream industries.

ELECTRICITY, GAS AND WATER

This sector includes the generation of bulk electricity, and transmission and distribution to end users. It also includes water abstraction, treatment and distribution activities for domestic and industrial needs.

Without a continuous supply of clean energy and water, mining and manufacturing cannot take place. Engineering skills are thus critical, not only to supply these services, but also for other sectors of the economy to thrive. While electrical and civil engineering practitioners are key to the delivery of electrical and water services, the equipment associated with generation and treatment processes also requires chemical and mechanical engineering skills.

CONSTRUCTION

This sector covers construction activities for buildings and civil engineering works, including:

- **Building works:** residential buildings, estates and slum redevelopment; and non-residential construction, including commercial, retail and industrial structures, public amenities, hotels and tourist facilities. Public amenities would include hospitals, schools and other educational facilities, sports and recreation facilities and public sector buildings.
- **Transportation and communication:** roads, rail, bridges, airports, ports, telecommunication systems and related physical infrastructure.
- **Water works and sanitation projects**: water supply, sanitation and sewerage schemes, dams, pumping and irrigation systems and related physical infrastructure.
- **Energy:** power stations, transmission and distribution lines, schemes for producing renewable energy and related physical infrastructure.
- **Other physical infrastructure:** defence, mining, agriculture and related infrastructure.

Construction covers new work, maintenance and repair, additions and alterations, the erection of prefabricated buildings or structures and construction of a temporary nature.

This sector largely uses civil engineering skills and construction project managers, but electrical and mechanical skills are required for equipment, lighting, heating and cooling, among others.

TRANSPORTATION AND COMMUNICATIONS

Transportation and communications are means of overcoming distance, either by moving goods or people, or by passing news and information from one person to another.

Transportation

The transportation sector includes the provision of passenger or freight transport by rail, pipeline, road, water or air, as well as associated activities such as terminal and parking facilities, cargo handling, storage, etc.

Mechanical and electrical engineering skills are required to design, manage, operate and maintain fleets. Aeronautical and marine engineering are subdisciplines of mechanical engineering, although in some countries they have become separate disciplines.

Civil and some electrical and mechanical engineering practitioners would be involved in the construction, operation and maintenance of the infrastructure networks.

Communications

The communications sector has become an integral part of our daily lives. From providing mainly voice services 30 years ago, communication has expanded to the transmission of voice, data, text, sound and video. Transmission facilities may be based on a single technology or a combination of technologies, with the use of satellite, wireless and extensive optical fibre networks having considerably enhanced transmission speeds. This sector transmits content, without being involved in its creation.

Electrical, electronic and systems qualifications are required in this sector. Some graduates would go on to complete a post-graduate qualification in telecommunications. More recently, dedicated telecommunications qualifications have been introduced in a number of countries.

The Internet of Things (IoT) will place further demand on the electronics and communications sectors, as the network of physical devices, vehicles, home appliances and other items are embedded with electronics, sensors and network connectivity which will enable these objects to connect and exchange data. Devices can be as diverse as heart monitoring implants, transponders on farm animals and links to security systems, among others. It is estimated that the IoT will consist of about 30 billion devices by 2020.

The positive and transformative effects the Internet of Everything (IoE) has had on government services, manufacturing, retail and health care have already been observed. It has allowed new customer and citizen experiences, improved operational efficiencies, breakthrough innovations and entirely new economic models for services and growth. At the city level, this includes smart grid solutions, traffic management, parking solutions and physical and cyber security. At the citizen level, the value comes from electronic payments and teleworking, among others. For enterprises, the IoE can be the deployment of sensors that provide real-time data, which when deployed with an overlay of data analytics, will allow proactive responses to changing conditions.

THE ENGINEERING LIFE CYCLE

Developing infrastructure, products or processes is not a trivial exercise, but requires many steps to ensure that a cost-effective and sustainable solution is developed, utilised and maintained. The engineering life cycle is shown in Figure 8.

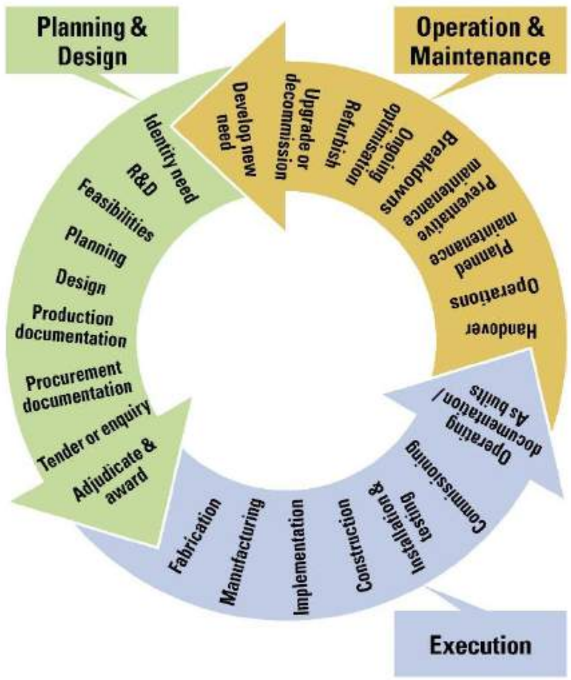


Figure 8: The engineering life cycle

Whether a road, a new mobile phone, a vehicle or a streamlined data processing system for a financial institution is being designed, it is necessary to investigate and identify the need, to carry out feasibility studies, planning and detailed design and to document the final solution before execution can begin. Once the development is complete, ongoing use, optimisation and maintenance must be managed. This cycle requires the dedication of engineering teams.

THE ENGINEERING TEAM

Engineering teams as we know them today have evolved into a multi-disciplinary hierarchy able to address all levels of engineering activities, from basic labour to the design of the most complex systems. The hierarchy has, however, evolved over time.

THE EMERGENCE OF THE ENGINEERING TEAM

Engineering has developed from a very rudimentary form of manual arts to a high level of science and research. Historically, engineering training was a hands-on, shop- or site-cultured process learned through various means of guilds, apprenticeships and simple on-the-job training.

The

science of modern-day infrastructure, which includes surfaced roads, steam (and now fuel, diesel or electric) engines, railway networks, bridges, tunnels, water-borne sewage removal, piped potable water and the light bulb, only began to emerge in the 18th century and dominated the development of major cities such as London and New York. Masters such as Macadam, the Stephensons, Bazalgette, Babbage, Brunel, Telford, Edison *et al.* pioneered new technologies which needed to be shared with future generations to support growing populations and the dawn of urbanisation.

It was realised that much of the theoretical knowledge learned or developed by these masters could be shared through tuition. Many masters wrote material that became standard works in which design calculations replaced the rules of thumb on which decisions had previously been made. Engineering was formally introduced to academia in the 1700s, and a theoretical, school-cultured engineer emerged, whose role it was to expand the implementation of new technologies. Courses concentrated on implementation techniques and developing many practical skills, such as drawing, surveying, managing machine shops, etc.

When the Western World reviewed its technological successes after World War II, it was realised that engineers generally did not perform as well as physicists in solving unusual problems. Many engineers had been ignorant of the science underlying the breakthroughs, and so the need for engineers to understand principles and concepts was recognised. After much debate, two tiers of engineering instruction were finally recommended. The first tier, the training of the engineer, would concentrate on more science and engineering science, and the second tier on technology training.

Thus, the engineering technician was born. The technician was to be equipped with practical know-how to complement the academic knowledge of the engineer, thereby forming what Frederik Philips, who served on the American Society for Engineering Education's Committee on Evaluation of Engineering Education in 1955, considered to be an *'unbeatable team fit to tackle any project'.*

In time, it was realised that the practice of engineering required a broader spectrum of expertise and an additional team member, the technologist, emerged. Technology training was extended to a Higher National Diploma, or Bachelor of Technology. The engineering team as we know it today is shown in Figure 9.

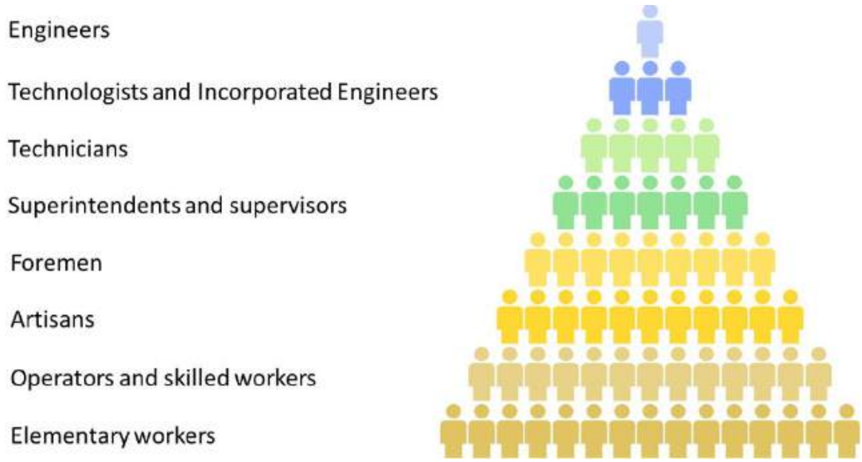


Figure 9: The engineering team

Considering Figure 10, broadly speaking, engineers should be 'innovators' responsible for complex tasks such as developing solutions to address new infrastructure or systems requirements, or enhancements to operations and maintenance. They may use engineering principles where necessary to develop unique solutions. They need to consider multi-disciplinary needs, overall resourcing and risks associated with the solutions.

Engineering technologists solve engineering problems by using proven techniques and are thus the 'implementers' who implement broadly defined tasks or projects proposed by engineers. They may also plan and oversee long-term strategies for implementation, operations and maintenance.

Engineering technicians are the backbone of infrastructure support, and are the 'doers' who carry out well-defined tasks such as managing safety, operations, maintenance, production, etc. They may source skills for operational activities and detect and respond to non-standard situations that arise.

In the planning phase, engineers and technologists play a major role, while in the implementation phase, technologists and many technicians, artisans, operators and elementary workers are required.

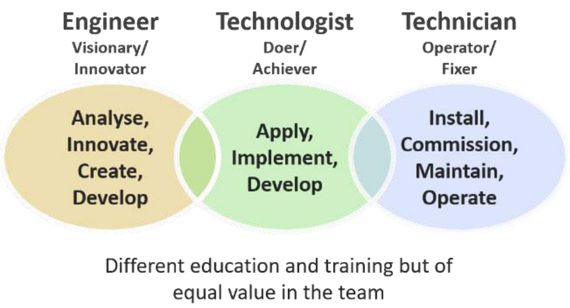


Figure 10: The role of engineers, technologists and technicians

There is no ideal ratio of engineer to technologist to technician. This varies per discipline and stage of the engineering life cycle.

ENGINEERING DISCIPLINES

The following are the main engineering disciplines covered in the study. Other occupations are derivatives of these. For example, an aeronautical or marine engineer would follow a similar programme to a mechanical engineer and would branch into the area of specialisation part way through the qualification. The descriptions are extracted from the Organising Framework for Occupations and the ECSA Discipline-specific Training Guidelines.

AGRICULTURAL ENGINEERING

An agricultural engineer performs and supervises engineering work concerned with planning, design, development, operation and maintenance of agricultural land, buildings, infrastructure, machinery, equipment, mechanisation, production and processing. Agricultural engineering practitioners generally concentrate on one or more of the following areas:

- Agricultural energy and renewable energy
- Agricultural product processing engineering
- Agricultural structures and facilities
- Agricultural waste handling and management
- Aquaculture engineering
- Mechanisation and refrigeration
- Hydrology, irrigation and water use management
- Natural resource and environmental engineering
- Post-harvest processes and food engineering
- Rural infrastructure engineering.

The use of technology is important in food processing and storage systems to add value to raw products to make them fit for human and animal consumption.

Need for engineers

CHEMICAL ENGINEERING

A chemical engineer designs and prepares specifications for chemical process systems, and for the construction and operation of commercial-scale chemical plants, and supervises industrial processing, fabrication and manufacturing of products undergoing physical and chemical changes. Typical tasks carried out by chemical engineering practitioners include:

- Conducting research, advising on and developing processes to refine crude oil and other liquids or gases to produce substances such as petroleum derivatives, explosives, food and drink products, medicines and synthetic materials
- Specifying chemical production methods, materials and quality standards and ensuring that they conform to specifications
- Establishing control standards and procedures to ensure the safety and efficiency of chemical production operations
- Designing chemical plant equipment for manufacturing chemicals and products
- Performing tests throughout the stages of production to determine the degree of control over variables, including temperature, density, specific gravity and pressure
- Monitoring and optimising production
- Performing laboratory studies to manufacture new products and testing proposed processes on a small scale in a pilot plant.

CIVIL ENGINEERING

A civil engineer plans, designs, organises and oversees the construction and operation of civil engineering projects. Typical tasks that civil engineering practitioners may undertake include:

- Conducting research and developing new or improved methods and materials
- Advising on and designing infrastructure such as roads, bridges, airports, ports, railways, dams, canals, pipelines, treatment works, waste-disposal and flood-control systems, and industrial and other large structures
- Determining, directing and specifying construction methods, materials and quality standards, and ensuring safety
- Organising and directing the maintenance and repair of existing civil engineering infrastructure
- Analysing soil conditions and designing structural foundations.

ELECTRICAL ENGINEERING

Electrical engineers are expected to plan, design, construct or manufacture, manage, operate and maintain materials, components, plants and systems for generating, transmitting, distributing and utilising electrical energy; electronic devices, apparatus and control systems for industrial systems, bio-medical and consumer products; computing, communication and software for critical applications; and instrumentation and control of processes, through the application of electrical, electromagnetic and information engineering sciences. Within the broad field of electrical engineering, practice areas or specialities include:

- **Electric Power Engineering:** comprising electrical systems, components, motors and equipment, control systems, illumination, signalling and communications, materials, products and processes
- **Electronic Engineering:** comprising electronic systems, instrumentation, computers and information systems, automation, materials, products or processes
- **Telecommunications:** comprising systems, devices and products, including broadcasting, digital signal processing, communications (fibre optics, radio, radar, satellite transmission) and telecommunications.

INDUSTRIAL ENGINEERING

Industrial engineers conduct research and organise and oversee the planning, design, implementation, operation and maintenance of industrial, manufacturing and production systems and operations, through systems engineering and supply chain management. They establish programmes for the coordination of manufacturing activities, assess cost-effectiveness and safety, and recommend improvements in the efficiency of operations in commercial, industrial and production environments. Practice areas include:

- Automation and control systems
- Enterprise resource management
- Industrial efficiency and machinery
- Manufacturing logistics and technology
- Operations research
- Process design
- Production
- Quality management
- Robotics and production automation
- Supply chain management.

MECHANICAL ENGINEERING

Mechanical engineers advise on and design machinery and tools for manufacturing, mining, construction, agricultural and other industrial purposes and the mechanical aspects of materials, products or processes. Machinery may include non-electric motors and engines; hulls, superstructures and propulsion systems; airframes, undercarriages and vehicles; mechanical plant and equipment for heating, ventilation and refrigeration; gears, pumps, pipework, valves etc. Practitioners generally concentrate on one or more of the following areas:

- Air-conditioning, heating and ventilation
- Automotive, diesel and transportation systems
- Fluid mechanics and thermodynamics
- Machine design and development
- Maintenance management
- Mechatronics
- Piping
- Power generation
- Pressurised vessels.

METALLURGICAL ENGINEERING

Extractive metallurgical engineers conduct research and plan, design, develop, construct, operate and maintain commercial-scale processes for the extraction of metals or intermediate compounds from ores by chemical or physical processes, including those at high temperatures. They are found in smelters, refineries and other processing plans. They may also develop, control and advise on processes used for casting, alloying, heat treating or welding refined metals, alloys and other materials to produce commercial metal products or to develop new processes.

Materials engineers investigate the properties of metals and alloys, develop new alloys and advise on and supervise technical aspects of metal and alloy manufacture, processing, use and manufacturing. They may also carry out residual life evaluations and predictions and failure analyses, and prescribe remedial actions to avoid material failures. Metallurgical engineering practitioners may be found in the following areas:

- Mineral processing
- Pyrometallurgy
- Hydrometallurgy
- Physical metallurgy
- Materials
- Welding
- Corrosion
- Quality assurance.

MINING ENGINEERING

Mining engineers involved in extraction and mining operations conduct research on and assess the feasibility, safety and productivity of mine locations. They also plan, design, develop, manage and optimise the extraction of surface and underground deposits. They ensure that underground resources such as minerals, metals, oil and gas are extracted safely and efficiently. Typical responsibilities include:

- Assessing the feasibility, potential and commercial benefit of new sites
- Ascertaining extraction risks
- Producing models or plans for possible mining sites
- Planning and implementing extraction systems
- Using specialist applications to maximise planning and production
- Monitoring and evaluating underground performance
- Managing construction projects
- Ensuring that equipment used and operations comply with health and safety requirements.

DERIVATIVE ENGINEERING QUALIFICATIONS

In countries with niche engineering requirements, several derivative or specialist engineering qualifications have emerged. The most notable are described below.

Textile engineering

Cotton is an important crop in several countries. To develop the value chain an interesting qualification, textile engineering, has emerged. This covers a combination of electrical, mechanical and process engineering, and courses in cotton growing, processing and yarn and fabric production.

Railway engineering

Given the major developments and upgrades required in the rail sector, the Instituto Superior de Transportes e Comunicações (ISTUC) in Mozambique has introduced a railway engineering degree covering aspects of civil, electrical, electronic and mechanical engineering to address the design, operations and maintenance of the perway, signalling, control systems and rolling stock. Due to its relevance in the region, the university is considering offering the qualification in English.

Aeronautical engineering

In countries involved in the design of aircraft or the maintenance of large fleets, a specific aeronautical engineering degree is offered. Essentially, it is a mechanical engineering degree, with specific subjects covering aerodynamics and flight mechanics.

Need for engineers

Environmental engineering
Environmental engineering qualifications include elements of civil and chemical engineering qualifications and the principles of soil science, biology and chemistry to allow graduates to develop solutions relating to recycling, waste disposal, and water and air pollution control, among others.

Marine engineering
In many coastal countries a marine engineering degree is offered. Essentially, it is a mechanical engineering degree, which considers the dynamics of wave action and the design, development, manufacturing, certification, maintenance and modification of ships and water-borne structures on the ocean, coastal waters, inland waters and underwater.

Mechatronics
A hybrid degree emerged from the 1970s combining mechanical and electronic engineering. However, given the level of automation that has become inherent in most devices and processes, mechatronics degrees today are multi-disciplinary and include a combination of mechanical, computer, telecommunications, systems and control engineering, electronics and robotics.

Software engineering
In several countries a stand-alone software engineering qualification is offered. Essentially, it is composed of electronic engineering with the addition of more software and systems subjects, to allow graduates to design, develop, test and evaluate software, operating systems, hardware systems and components, and computer networking. In other countries software engineering is offered as an elective in the final year of electrical and electronic engineering qualifications.

ESTIMATED NUMBERS
Detailed data per discipline and category was not readily available in many countries. However, estimates of the percentages and totals per discipline are shown in Figure 11, Table 4 and the split by gender is shown in Table 5.

Reliable data could only be gathered from some registration bodies which often only represents a small percentage of the engineering workforce, as registration is not compulsory in many countries. Their data, in combination with voluntary association membership information, graduation history, employment profiles, and consulting and contracting skills information, where available, has been used to estimate ratios and extrapolate the samples received to the overall engineering population. The data should be used with caution as many samples were small relative to the population and the engineering skills considered to be available.

The main disciplines, such as chemical, civil, electrical, mechanical, metallurgical and mining engineering, were well understood, but emerging and specialist qualifications such as mechatronics, telecommunications, textiles or industrial engineering, etc. were only evident in some countries. Where specialist qualifications are not offered, the sub-disciplines are covered in the qualifications of one of the main disciplines in Figure 11 and Table 4.

It is possible that the number of civil practitioners is overestimated, as this is the most regulated of the engineering disciplines in terms of public health and safety, hence more data was available about the number of civil engineering practitioners in most countries. Where more detailed data was available it was found that electrical engineering presented the largest group, as electrical practitioners are involved not only in infrastructure development, but mining, manufacturing, electronics, automation, system development and telecommunications among others. Mechanical engineering is the second largest group in South Africa due to the extent of the manufacturing and mining sectors. Mechanical practitioners are required in all industries and should be factored into skills planning, as they also play a role in power generation (including renewable

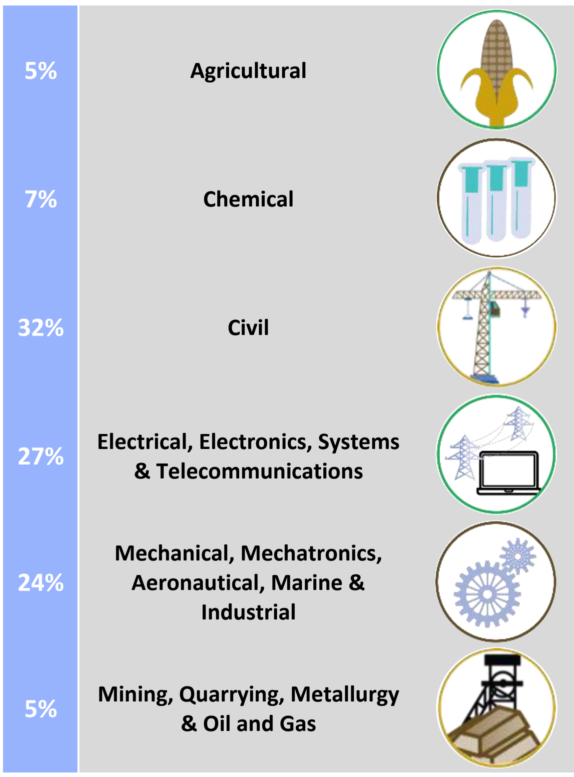


Figure 11: Percentage distribution of disciplines in the region

energy), water treatment (including desalination), agriculture, and heating, air conditioning and ventilation (HVAC) among others.

The extent of the use of agricultural engineers was difficult to gauge as there are few dedicated agricultural engineering associations and agricultural engineers were not found in many registering body datasets. In the French and Portuguese speaking countries, agronomy qualifications also include engineering subjects hence agronomists are classified as engineers, which is reflected in the higher numbers in those countries in Table 4.

Due to the emphasis placed on analysis and problem-solving in engineering qualifications, engineering practitioners are to be found not only in the engineering sectors as described in this chapter, but in many industries that are affected by or influence engineering decisions, such as in finance, insurance, investments, property development, asset management etc. Practitioners are also found in the tourism sector in some of the island states, where it is the responsibility of resorts to provide and operate their own water services and energy supplies.

Many practitioners, mostly civil, electrical and agricultural engineering are involved in the NGO sector, working on community projects to address the delivery of basic services and enhance agricultural production. Engineering practitioners are also involved in delivering training and managing professional bodies.

Data relating to the total in Zimbabwe was taken from the 2014 Labour Force Survey, but the Zimbabwe Institution of Engineers advised that by the end of 2018, the numbers had dropped due to the poor state of the economy, company closures, and the need to seek work outside of the country.

Table 4: Estimated number of engineering practitioners per discipline

COUNTRY	Agriculture	Chemical	Civil	Electrical, Electronics, Systems & Telecomms	Mechanical, Mechatronic, Aeronautical, Marine & Industrial	Mining, Quarrying, Metallurgy & Oil and gas	Total
Angola*[1]	552	368	4 770	1 718	944	649	9 000
Botswana	30	100	2 600	1 650	1 270	350	6 000
DRC	6 270	550	2 660	3 370	3 400	1 750	18 000
Eswatini	120	35	685	520	230	10	1 600
Lesotho	25	20	500	350	195	60	1 150
Madagascar	1 110	400	2 900	3 040	2 700	850	11 000
Malawi	301	25	1 255	1 079	508	31	3 200
Mauritius	20	150	2 200	1 550	1 070	10	5 000
Mozambique*[1]	989	747	5 103	2 401	1 760	*[2] See note	11 000
Namibia	20	55	1 200	840	520	165	2 800
Seychelles	-	3	143	178	184	2	510
South Africa	900	10 175	30 950	32 350	31 325	4 300	110 000
Tanzania	1 550	1 475	12 350	7 400	6 375	850	30 000
Zambia	350	700	3 800	3 300	2 600	1 250	12 000
Zimbabwe	180	400	2 360	1 850	1 810	1 000	7 600
TOTAL	**12 417**	**15 203**	**73 476**	**61 596**	**54 891**	**11 277**	**228 860**

*[1] Only engineers are reported on in these countries

*[2] The Ordem dos Engenheiros de Moçambique reports civil and mining engineering as one total which is reflected under Civil

Table 5: Percentage females from selected bodies per country where available

AGE GROUP	Angola	Botswana	Eswatini	Madagascar	Malawi	Mauritius	Mozambique	Namibia	South Africa	Zimbabwe
25-34	10.0%	15.4%	17.6%	40.6%	10.9%	23.5%	14.9%	21.3%	19.1%	10.0%
35-49	9.5%	8.7%	10.3%	20.6%	6.2%	9.2%	10.5%	15.1%	9.1%	6.1%
50+	7.5%	5.0%	0.0%	20.3%	2.6%	1.3%	5.9%	3.6%	1.8%	3.1%
TOTAL	**8.8%**	**9.9%**	**8.2%**	**23.2%**	**6.2%**	**8.7%**	**10.6%**	**14.3%**	**10.4%**	**6.2%**
Source	OEA	ERB	AESAP	OIM	MIE	CRPE	OrdEM	ECN	VAs	ZIE

Chapter 3

Developing professionals

Prospective professionals follow a protracted development pathway of at least 8 to 10 years after leaving school before they are able to operate independently.

THE ENGINEERING SKILLS PIPELINE

The engineering skills pipeline is shown in Figure 12. The requirements to succeed are as follows:

- **Schooling:** Demonstrate an aptitude for mathematics and science as required by each programme in higher education.
- **Theory:** Complete an accredited professional degree or diploma through a university, polytechnic, university of technology or college.
- **Workplace:** Complete a workplace training phase usually over three or more years under supervision and mentorship. In terms of the various registration Acts throughout the region, during this phase the graduate is known as a candidate or graduate-in-training who is required to do the following:
  - Follow a prescribed range of activities or follow best practice guidelines, complete logbooks or reports as required by the professional body, and develop a portfolio of evidence.
  - Be exposed to an adequate range of increasingly complex activities and take increasing responsibility, until able to perform as an independent professional.
  - Submit logbooks, portfolios of evidence and reports as required, either during the course of development or when ready for assessment for the purpose of registration.
- **Assessment:** Be assessed through an examination or peer review or both to determine whether the required level of competence has been achieved.
- **Registration:** Be awarded a designation commensurate with their education, training and experience.
- **Professional practice:** Work in a professional environment which values engineering professionals, offers them opportunities to develop as experts or to grow into management and leadership roles and affords them the opportunity to make technical and strategic decisions. Experienced professionals must:
  - Adhere to the Code of Conduct prescribed by the relevant Statutory Council and work within the practice area for which their education, training and experience has rendered them competent
  - Continue to develop and keep up to date by actively engaging in Continuing Professional Development (CPD).
- **Institutional commitment:** Work in an environment where appropriate staff, systems, processes, support and necessary service providers are in place or may be appointed.
- **Investment:** Work in an environment where investment in planning, development, operations and maintenance of infrastructure, products, systems and/or processes takes place.

There are numerous bottlenecks in each of these phases which need attention. Furthermore, regional standards and alignment are critical for countries to benefit from and support each other's development.

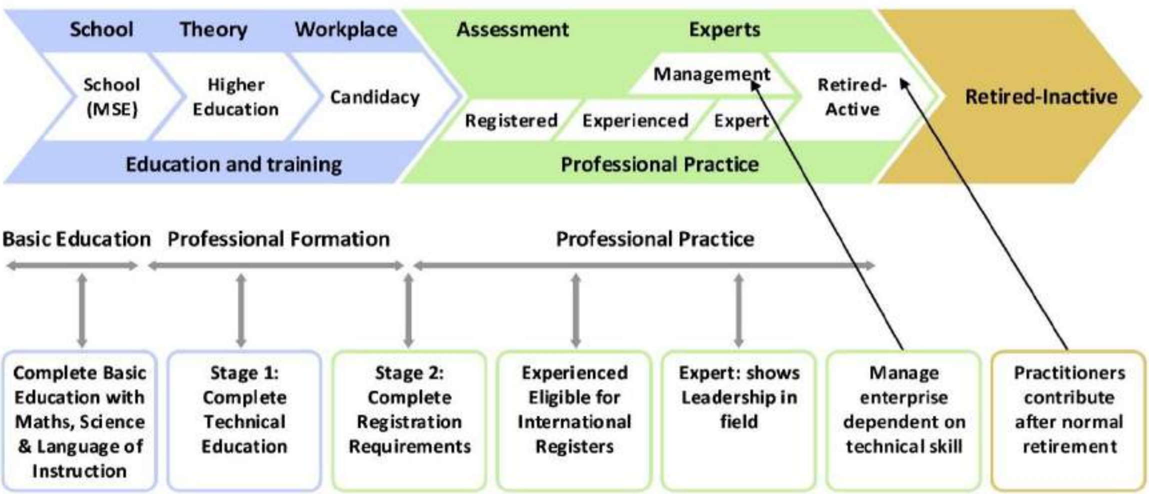


Figure 12: The engineering skills pipeline

(Acknowledgement: Originally drawn by Prof. Hu Hanrahan)

The report will look at the challenges per phase, but to understand possible solutions, consideration of appropriate standards is necessary.

THE SADC QUALIFICATIONS FRAMEWORK

In the late 1980s the idea of a National Qualifications Framework emerged in the UK. Such a framework would measure qualification levels in terms of outcomes achieved, without prescribing learning pathways or programmes. Level descriptors were defined to determine the level at which a qualification should be pegged. South Africa, along with Australia and New Zealand, among others, embraced this thinking and South Africa was the first country in Africa to develop a National Qualifications Framework. Initially launched with eight levels, the framework was expanded to 10 levels covering all major exit levels from early secondary school to the award of a doctorate as follows:

- General certificate
- Elementary certificate
- Intermediate certificate
- National certificate
- Higher Certificate
- Diploma
- Bachelor's degree
- Bachelor Honours degree
- Master's degree
- Doctoral degree.

In SADC, a committee known as the Technical Committee on Certification and Accreditation (TCCA) was constituted to:

- Facilitate mutual recognition of qualifications in all Member States
- Harmonise qualifications wherever possible
- Promote the transfer of credits within and among Member States, and even beyond, to facilitate the mobility of students, teachers and lecturers
- Create SADC regional standards where appropriate.

THE SADCQF

Emerging from the work of the committee, a regional qualification framework has been launched, known at the SADC Qualifications Framework (SADCQF) which countries are called upon to use for developing their own qualifications frameworks. The descriptors consider knowledge, skills, autonomy and responsibility.

All SADC countries have committed to developing frameworks and have progressed to a greater or lesser degree to date, using a 10-level framework, guided by the SADCQF. There is concern, however, that the lower levels are lower than those defined in the qualification frameworks of countries who have been using this approach for some time. It has also been found that the complexity of subjects at the school leaving level varies which poses a challenge when considering tertiary education entrance criteria. The TCCA still has much work ahead to ensure that different level descriptors per country are understood and aligned.

The descriptors consider knowledge, skills, autonomy and responsibility. The levels under discussion in this study are Levels 6 to 8, where:

- **Level 6** relates to the **engineering technician** who is expected to have specialist knowledge in a wide range of technical subjects and must be able to manage processes and personnel.
- **Level 7** relates to the **engineering technologist** who is expected to understand the principles relating to specialist areas, solve problems and design and manage processes and personnel.
- **Level 8** relates to the **engineer** who is expected to understand the principles relating to the entire discipline, be able to think critically, conceptualise and develop original solutions, and prepare strategic plans, taking complete accountability for the management of resources and the supervision of others.

QUALITY ASSURANCE AUTHORITIES

Each country has committed to set up a quality assurance authority to develop the local framework and take responsibility for assessing the levels of qualifications offered and ensuring that the standard of qualifications at each level is maintained, through various assurance methods.

Quality assurance authorities have been set up as stand-alone statutory bodies in several countries, while in other countries, assurance is handled through the ministries of education. In assessing and accrediting qualifications, many countries call on associated professional or industry bodies to participate in assessments, or to handle assessments formally on their behalf, as it would not be practical to build a set of expertise for each qualification within the assurance authority or body. In South Africa, three statutory bodies, covering general education, occupational qualifications and higher education, have been set up to handle the accreditation of qualifications which must satisfy level descriptors set by the South African Qualifications Authority (SAQA).

INTERNATIONAL STANDARDS

Ensuring substantial equivalence of standards for each of these stages in each country presents a challenge. For instance, is an engineering degree in one country equivalent to an engineering degree in another country, or does professional registration in one country demand the same level of problem-solving and complexity of work as in another?

TERTIARY EDUCATION

Recognising the challenges of qualification equivalence, several international best practice standards have been developed.

International Engineering Alliance (IEA)

Several countries agreed in 1989 to work towards aligning and accrediting engineering qualifications and to recognise their equivalence in signatory countries. The first agreement, known as the Washington Accord, was focused on the content and outcomes of engineering degrees, and has made a considerable impact in improving engineering education. Two further accords have been signed, known as the Sydney and Dublin Accords, which recognise the substantial equivalence of engineering technologist and engineering technician qualifications respectively.

The cornerstone of the agreements has been the development of agreed graduate attributes, which students must achieve when exiting each programme. Assessment of qualification equivalence requires the assessment of the programme design, the resources committed to the programme, the teaching and learning process, and of the student experience and results, including confirmation that the graduate attributes have been satisfied.

The theoretical requirement for each Accord is defined as follows:

- **Dublin Accord (Technician):** A descriptive, formula-based understanding of the natural sciences and a procedural understanding of mathematics, numerical analysis and statistics applicable to the subdiscipline.
- **Sydney Accord (Technologist):** A systematic, theory-based understanding of the natural sciences and a conceptually based understanding of mathematics, numerical analysis, statistics and aspects of computer and information science to support analysis and use of models applicable to the subdiscipline.
- **Washington Accord (Engineer):** A systematic, theory-based understanding of the natural sciences and a conceptually based understanding of mathematics, numerical analysis, statistics and formal aspects of computer and information science to support analysis and modelling applicable to the discipline.

These reflect those of the SADCQF descriptors for levels 6 to 8, although there is some concern that the SADC level 6 requirements may not be as demanding as those defined in the Dublin Accord.

Rather than accrediting institutions, the approach is to accredit each qualification offered by an institution. It is conceivable that one discipline could be well resourced, and another not. There are rigorous rules in terms of accreditation to retain recognition, including reviews every five years by local reviewers, and reviews of one or more qualifications per country every six years by an international team of experts selected through the accreditation committees of the IEA.

By 2016, registering or professional bodies in Australia, Canada, Ireland, New Zealand, the United Kingdom, the United States, Hong Kong, South Africa, Japan, Singapore, Korea, China, Malaysia, Sri Lanka, India, Turkey and Russia had become recognised accrediting bodies, and several more, mostly from South-East Asia and Latin America, hold provisional status, while others, including Mauritius, are working towards provisional status.

Being the only signatory to the Accords in Africa, the Engineering Council of South Africa (ECSA) has been assisting higher education institutions (HEIs) in the region with assessments and recommending areas in which they need to strengthen their programmes to achieve recognition under the Accords.

European Network for Accreditation of Engineering Education (ENAEE)

The ENAEE is the European network which authorises accreditation and quality assurance agencies to award the EUR-ACE® label to accredited engineering degree programmes.

As with the IEA, a set of standards and guidelines for accreditation of engineering programmes covering student workload requirements, programme outcomes and programme management and resourcing are specified to ensure that quality programmes are offered. In the case of the ENAEE, only Licentiates and Master's degrees are considered.

Registering bodies in the United Kingdom, Ireland, Austria, Belgium, France, Germany, Italy, Portugal, Spain, Switzerland, Denmark, Finland, Russia, Turkey, Romania, Poland, Slovakia and Kazakhstan have become authorised agencies able to award the EUR-ACE® label, while several others are associate members working towards full membership.

Best Practice in the accreditation of engineering programmes

In 2015, the ENAEE and the IEA agreed to develop jointly a Best Practice document. It serves both the ENAEE and the IEA in their ongoing operations and is of interest to bodies that are either forming new agencies or developing accreditation systems to the level required by either EUR-ACE® or the IEA Accords.

This is a significant achievement as it represents the agreement and common understanding of best practice in engineering accreditation by the 26 countries/accreditation agencies involved in the two organisations worldwide.

Conseil Africain et Malgache pour l'Enseignement Supérieur (CAMES)

CAMES (African And Malagasy Council for Higher Education) was formed soon after the independence of several French-speaking African states to address harmonisation of curricula, enhance mutual recognition of higher education qualifications and promote professional and student mobility between its members. The CAMES guidelines cover all qualifications, not just engineering.

Currently, CAMES member countries are Benin, Burkina Faso, Burundi, Cameroon, Central African Republic, Chad, DRC, Gabon, Guinea, Guinea-Bissau, Equatorial Guinea, Ivory Coast, Madagascar, Mali, Niger, Rwanda, Senegal and Togo.

The Institut Supérieur de Technologie d'Antananarivo (IST-T) in Madagascar was delighted to have its accreditation renewed in January 2017.

The World Federation of Engineering Organisations (WFEO)

WFEO was founded in 1968 under the auspices of UNESCO and represents more than 90 national engineering institutions. In essence, its role is to provide information and leadership to the engineering profession, society and governments on issues of concern to the public or the profession.

As part of its commitment to supporting the delivery of the SDGs, WFEO has developed a 2030 Action Plan. One of the aims is to play a leading role in the '… *development of engineering capacity of appropriate recognised standards for sustainable development*'.

In December 2015, WFEO signed an agreement with the IEA, committing to use the IEA Accords as a single consistent global standard for engineering education. They also jointly committed to work towards building the capacity of national accreditation bodies to facilitate their joining the Accords.

A SADC Accord?

The disparity in engineering qualifications in the SADC region requires attention. Consideration needs to be given to using the guidelines developed by these bodies to set milestones for tertiary education institutions to work towards ensuring that their qualifications are eventually on par with international best practice.

It is critical that engineering degrees produce graduates who are able to solve problems and become the specialists and strategic thinkers of the future. For too long has it been necessary to harness international expertise to solve complex problems.

Professor Clive Chirwa from the Copperbelt University in Zambian, among others, has recognised this need. He has expressed concerns that Zambian engineers were maintenance engineers and not innovative. He called upon them to move to a '*… higher level of excellence*' and come up with '*… the solution to whatever problems that this nation may have*'. It is important that local engineers should solve local problems, as often international service providers have come up with solutions that do not recognise the African context or needs.

Cost of accreditation and quality assurance

Alignment with tried and tested international standards is something for which the region should strive. However, substantial funding needs to be set aside, not only for supporting all institutions to enhance their offerings, but also to fund ongoing accreditation and quality assurance activities.

In a review of engineering education in Zambia it was recognised that there were neither robust accreditation nor adequate quality assurance processes in place, with one of the main reasons being the prohibitive cost of bringing external examiners from universities outside Africa.

It will be necessary to build regional accreditation and quality assurance teams.

PROFESSIONAL REGISTRATION

Worldwide, different measures have been put in place to determine when an engineering graduate is ready for professional registration.

Developing professionals

Before listing and evaluating these approaches, it is necessary to consider briefly the need for registration. The intention is to recognise those who have achieved the competence to work as independent practitioners, able to analyse needs and develop sustainable solutions in the interests of public health and safety, among other considerations. This requires more than knowing the theory. It requires that graduates have learnt to apply their undergraduate theory in the context of engineering problem-solving.

In 1956, Dr Benjamin Bloom, an educational psychologist, developed a taxonomy to promote higher forms of thinking, such as analysing and evaluating, rather than just remembering. His original model has been modified to be more relevant to today's action learning approaches, but nevertheless captures the abilities that engineering professionals should develop. They are, in the context of engineering problem-solving:

- **Remember:** Recall facts and basic concepts previously learned.
- **Understand:** Comprehend and be able to explain the meaning of lessons and concepts.
- **Apply:** Use what was learned in the classroom in new situations in the workplace.
- **Analyse:** Examine something in detail, considering all the facts, variables and inferences, to discover more about it.
- **Evaluate:** Make judgement calls about options, needs, impacts and appropriate solutions.
- **Create:** Develop a sustainable solution unique to the situation.

Developing from a novice graduate to a competent professional takes time and support. The support suggested and the progression are described in Table 6 (published in the ECSA *Training and Mentoring Guide for Professional Categories* (see www.ecsa.co.za)).

Readiness for professional registration should test levels of thinking in Bloom's Taxonomy and the level of responsibility assumed when solving complex engineering problems.

Approaches to registration worldwide include:

- **Recognition of an accredited qualification** which allows graduates to operate independently as long as they have completed an engineering qualification accredited by the registering body. This approach does not ensure that graduates have gained meaningful practical experience under the guidance of seasoned professionals. It either results in graduates limiting themselves to simple projects and not developing to their full potential, or in graduates taking on work for which they are not sufficiently experienced, with the associated risk of developing unsafe or costly solutions.

- **Set time to registration** which allows graduates to register professionally after completing a specified number of years in the workplace. This does not measure the range or complexity of experience gained, or the level of responsibility taken.
- **Professional exam** which generally has the disadvantage of testing more theory along the lines of undergraduate exams and the graduate's ability to perform processes, rather than assessing his or her critical thinking and problem-solving abilities. In cases where the professional exam is a day-long applied exam requiring graduates to complete a detailed design or develop a solution, results are generally low, as the range of design questions set in the exams are generally too limited to cover the range of

Table 6: Increasing responsibility levels assumed during graduate development and training

(Source: ECSA R-04-P)

LEVEL	NATURE OF CANDIDATE WORK	RESPONSIBILITY OF CANDIDATE	LEVEL OF SUPERVISOR/ MENTOR SUPPORT
A. Being exposed	Undergoes induction, observes work of competent practitioners	No responsibility	Mentor explains challenges and forms of solution
B. Assisting	Performs specific processes under close supervision	Limited responsibility for work output	Supervisor/mentor coaches, offers feedback
C. Participating	Performs specific processes as directed with limited supervision	Full responsibility for supervised work	Supervisor progressively reduces support
D. Contributing	Performs specific work with detailed approval of work outputs	Full responsibility to supervisor for immediate quality of work	Candidate articulates own reasoning and compares it with those of supervisor
E. Performing (responsible but not accountable)	Works in a team without supervision, recommends work outputs	Responsibility to supervisor is appropriate to a registered person	Candidate takes on problem-solving without support, at most limited guidance

the types of project on which graduates may have been involved.

- **Professional report and peer interview** which is a competence-based assessment that allows reviewers to determine the range and complexity of work undertaken and the ability to solve problems and take responsibility.

Several of the above do not test the development of all the Bloom's levels of thinking. The final registration assessment model as listed above is the most reliable approach, as reviewers can be matched to the subdiscipline areas in which graduates have practised and can test that they have mastered problem-solving and decision-making in these areas. This approach should be adopted as a standard in the region.

International Engineering Alliance (IEA)

The IEA also considers registration alignment. Over and above the Accords, it has developed agreements to ensure alignment of competency standards and equivalence of the level of practice for professional registration, based on experience, the complexity of work and responsibility carried. These agreements are known as the:

- International Professional Engineers Agreement (IPEA)
- International Engineering Technologists Agreement (IETA)
- Agreement for International Engineering Technicians (AIET)
- Asia-Pacific Economic Cooperation (APEC) agreement, which is in place with a number of Asia-Pacific countries for purposes of recognising the 'substantial equivalence' of professional competence in engineering in those countries.

International Registers have been set up for engineers and technologists. These are known as the International Professional Engineers Register (IPER) and the International Register of Professional Engineering Technologists (IRPET). Each signatory country manages its part of the register. The requirements are more stringent than professional registration, requiring at least seven years of experience after graduation, and having had at least two years in responsible charge of engineering work. Applicants must hold an accredited engineering qualification, must be professionally registered in their home country and must demonstrate that they are keeping up to date through CPD activities. The postnominals for the international engineer and technologist are Int PE and Int ET respectively.

Registration on the registers ensures that professionals can have their professional standing recognised by signatory countries, thereby contributing to the globalisation of professional engineering services. This is of particular benefit to organisations that are providing services in many countries, but it also adds value to individuals who may wish, at some stage, to work outside their country.

European Federation of National Engineering Associations (FEANI)

FEANI is a federation of professional engineers that unites national engineering associations from 34 European Higher Education Area (EHEA) countries. It is striving for a single voice for the engineering profession in Europe and wants to affirm and develop the professional identity of engineers.

FEANI has defined a quality professional title 'European Engineer' (EUR-ING) for professional engineers based on a sound education and assessed professional experience. The FEANI proprietary professional title is a *de facto* quality standard recognised in Europe and worldwide, and particularly in those countries that do not regulate the profession.

FEANI uses a competence standard to assess applicants which is very similar to the competences expected by the frameworks of the IEA. A comprehensive written submission is required outlining experience, and rigorous assessments take place against the competences required. The standard applies only to engineers.

The WFEO approach

As part of its 2030 Action Plan, WFEO has also committed to the IEA Agreements for a single consistent global standard on professional registration and they have jointly agreed to work towards building the capacity of national competence assessment bodies to facilitate their joining the Agreements.

THE SADC IMPERATIVE

In SADC, considering the number of regional projects in which multinational engineering teams need to participate, it is important that education and professional practice standards are aligned to allow articulation and mobility throughout the region. Considering the decision taken by WFEO to adopt the IEA Accords and Agreements, the region should also set its sights on attaining the standards developed by the IEA for each category of engineering education and professional registration.

Chapter 4

The flow of skills

It is often assumed that self-regulation mechanisms in a market economy ensure the necessary supply to the labour market, but there is evidence of this not being the case in the SADC region. Experienced engineering professionals are reported to be in short supply and vacancies exist in many public sector structures. At the same time, reports indicate that engineering graduates are unable to find employment, leading to the growing phenomenon of the 'unemployed graduate'.

To understand and address the mismatch, overall data on demand and supply is required. Adequate data on the demand for and supply of skills in the region is not available and a combination of approaches has been adopted to build a picture of the current engineering skills base, and the future potential capacity and requirements. Figure 13 captures the flow of skills. The current workforce is not static, but rather reduces over time as people exit the workforce for various reasons, and others enter. Given that there is ongoing growth, methods of increasing the inflow need to be considered to grow the workforce on an ongoing basis. To build a comprehensive picture, economic growth, demand, and current and future supply must be understood.

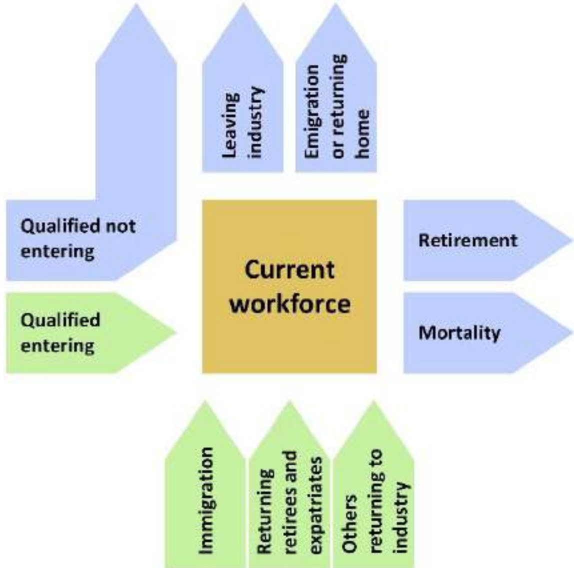


Figure 13: The flow of skills
(Acknowledgement: IMechE. Demand and supply of engineers in the UK)

ECONOMIC GROWTH AND DEMAND

Despite many grand plans, SADC countries have not succeeded in achieving the growth targets considered necessary to address poverty and inequality. As shown in Figure 14 few countries had achieved the SADC target of 7% by 2010.

Growth to 2015 improved, but 2016 saw a drop in several countries, as shown in Table 7. Projections to 2023 estimated by the IMF show a positive movement in many countries.

Conventional wisdom suggests that economic growth creates more job opportunities and will address unemployment. The difficulty, however, is determining the magnitude of employment opportunities.

It is important for growth to occur in sectors that have the potential to absorb labour on a large scale. Some sectors and activities are more employment-intensive than others, such as manufacturing and construction.

The impact of GDP growth on employment in agriculture is found to be limited as growth often has more to do with improvement in productivity than

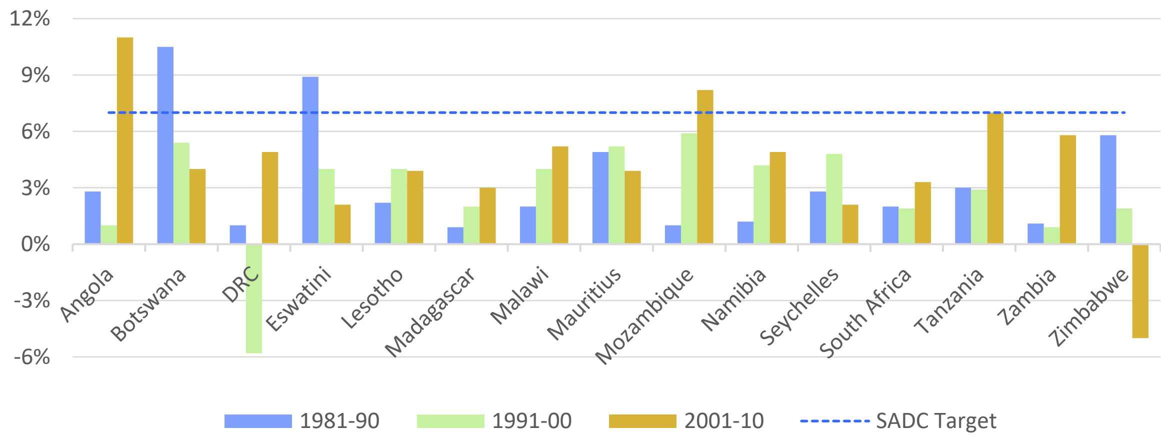


Figure 14: Real GDP growth rate in SADC countries
(Source: IMF, 2015)

employment. The agro-processing sector, however, has a relatively larger impact on employment. Furthermore, when economic conditions improve, companies often invest more in technology than in taking on an increasing number of employees, or they extend the working hours of existing staff as a low-risk approach to coping with growth.

A study carried out by Khan in 16 developing countries showed that no country's employment growth equalled its economic growth. He found the elasticity of employment with respect to GDP growth to be 0.7. Another study showed that for every 1% of GDP growth, total employment grew between 0.3 and 0.38 percentage points.

Data from the International Labour Organisation (ILO) and the World Bank suggest that elasticity ratios in the SADC region range from 0.2 in Mozambique and Lesotho to 1.6 in Madagascar. However, the ratio in most SADC countries is between 0.3 and 0.7, with an average of 0.48. Given the focus on industrialisation and growing the manufacturing sector, an elasticity ratio of 0.7 has been used for projections in this study, i.e. for a projected growth in GDP of 5%, an increase of 3.5% is included for the growth in the number of engineering skills required in the workforce.

According to the AfDB, 0.7 represents the desirable value for developing countries and is based on the elasticity in the Republic of Korea during the 1970s, when the country had a level of development and resource endowment comparable to that of some African countries.

EXPANSION DEMAND

Expansion demand refers to the increasing demand required to accommodate growth. To estimate expansion demand, the current number in the workforce is used and projections are based on percentage growth recorded in 2017. A second projection that could be used to estimate expansion demand is the growth projections suggested by the IMF for 2018 to 2023. A third set of expansion demand projections could be based on the Agenda 2063 growth projections of 6% from 2015 to 2020 and of 8% from 2021 to 2050. In most countries the latter growth seems unrealistic, given the limited growth that has taken place in recent years.

REPLACEMENT DEMAND – LOSSES

Replacement demand relates to replacements required in the workforce for those who are likely to retire, emigrate, change jobs or pass away. Percentages for each variable per country were established to calculate the number necessary to replace the losses.

Retirement

Retirement was calculated using the age profiles from 25 to 65 per country, and assuming that the age group over 65 had retired.

Migration

Net migration is the difference between the number of persons entering and leaving a country during the year per 1 000 persons (based on the mid-year population). An excess of persons entering the country is referred to as 'net immigration' and was added to the gains (discussed under *Supply*). An excess of persons leaving the country is referred to as

Table 7: Summary of percentage economic growth in SADC 2012 to 2023

COUNTRY	ACTUAL GROWTH						PROJECTED GROWTH						
	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2018 - 2023
Angola	5.2	6.8	4.8	3.5	3.5	-2.5	-0.1	3.1	3.2	3.2	3.7	3.8	2.8
Botswana	4.5	11.3	4.1	-1.7	4.3	2.4	4.6	3.6	4	4.1	4.2	5.5	4.3
DRC	7.1	8.5	9.2	9.2	8.5	3.4	3.8	4.1	4.3	4.4	4.6	4.7	4.3
Eswatini	3.5	4.8	3.6	1.1	0	1.6	1.3	0.4	0.4	0.4	1.6	2	1.0
Lesotho	4.9	2.2	2.2	3	2.5	-1.6	0.8	1.2	1.1	4.8	4.3	1.3	2.3
Madagascar	3	2.3	3.3	3.1	4.1	4.2	5	5.4	5.3	5.2	4.9	4.9	5.1
Malawi	1.9	5.2	5.7	3	4.5	4	3.3	4.7	5	5.5	6	6.5	5.2
Mauritius	3.2	3.2	3.6	3.4	3.8	3.8	3.9	4	4	4	4	4	4.0
Mozambique	7.2	7.1	7.4	6.6	3.8	3.7	3.5	4	4	4	4	11.1	5.1
Namibia	5.1	5.1	4.5	4.8	5	-0.8	1.1	3.1	3.7	3.4	3.3	3.4	3.0
Seychelles	3.7	6	4.5	5	4.5	5.3	3.6	3.3	3.3	4.1	4	3.3	3.6
South Africa	2.2	2.5	1.7	1.3	0.3	1.3	0.8	1.4	1.7	1.8	1.8	1.8	1.6
Tanzania	5.1	7.1	7	7	7.1	6	5.8	6.6	6.6	6.4	6.4	6.4	6.4
Zambia	6.8	6.7	5.6	5.6	6.2	3.4	3.8	4.5	4.5	4.5	4.5	4.5	4.4
Zimbabwe	10.6	3.3	3.1	3.2	3.9	3.7	3.6	4.2	4.7	4.8	5	5	4.6

'net emigration' and was added to the losses. Migration statistics from the United Nation's Population database were used. The sources used are detailed in Chapter 5, under *Demographics and the economy*.

Mortality

Mortality rates for the age profiles from 25 to 65 per country were used.

Leaving the industry

There are no studies giving an indication of the rate at which professionals leave the industry. This tends to vary, depending on the state of the economy. Alumni research gathered from a number of South African universities, and anecdotal evidence from 30- and 40-year graduate reunions, suggests that some 0.5%, on average, per year have left their original field and have moved into other industries.

The number required to replace those no longer in the industry is the total of the above four factors which must be accommodated by way of additional supply coming into the industry.

SUPPLY

Supply is made up of the current workforce and, in time, those entering the industry from various sources, namely tertiary education, nationals returning from overseas, retirees re-entering the industry, those returning who had previously left the industry and net immigration as discussed under *Migration*.

THE WORKFORCE

Determining the number in the workforce was not a trivial exercise. Theoretically, each country's Labour Force Survey should provide this data, but only in South Africa and the Seychelles was it possible to extract data down to occupation level. That being so, the sample used for carrying out labour force surveys is very small, and the Seychelles National Bureau of Statistics warned that using values down to occupation level was not exact but would offer an indication. Data from three years of the South African Quarterly Labour Force Surveys (QLFS) was used to give an average, as data varies significantly from quarter to quarter, depending on the locality of the sample.

All other countries simply show the total number employed under the major occupational groups, namely:

- Legislators, senior officials & managers
- Professionals
- Technicians & associated professionals
- Clerks
- Service workers, shops & market sales workers
- Skilled agricultural & fishery workers
- Craft & related trades workers
- Plant & machine operators & assemblers
- Elementary occupations
- Armed forces.

Each category covers many other disciplines such as medical, teaching, legal, financial and religion in the case of professions, and the range of technicians covers not only engineering technicians but hairdressing, catering and entertainment technicians, among others. It was thus necessary to work with the engineering institutions and associations in each country to understand the make-up of their membership and solicit an estimate of the percentage of engineering practitioners they represented. Where there were several such bodies in a country, comfort was found when several estimates agreed.

Some countries, notably Namibia and Botswana, had carried out detailed research in the past few years, which was used to provide a more accurate picture. In other countries, it was necessary to try to establish the total workforce by gathering data from the major employers such as water, electricity, transport and telecommunication utilities, and major manufacturing companies and mining houses.

Where regulations existed for construction and consulting companies to be registered, it was possible to estimate the number of engineering practitioners in the construction sector using the company category and associated criteria.

The numbers in the workforce for all countries are estimates. The only way to be sure of the numbers is to carry out a complete census of all engineering sectors and employers per country. Botswana, harnessing a large team of students, has carried out such an exercise, which has given a good idea of the spread of disciplines per sector. With a relatively small population, and industry and government located mainly in Gaborone and a few smaller centres, this was possible. In countries with large populations, several major centres and large manufacturing sectors, this would be a huge task.

As national labour force and household surveys do not gather data down to the level required, alternative methods of accurately determining the active labour force need to be considered. An option could be to expand online personal tax return systems to ask tax payers for comprehensive occupation data. This would offer an annual snapshot of the employment of all who are in formal employment.

TERTIARY EDUCATION

It was necessary to establish the total number graduating each year and the numbers projected from newly opened private institutions or new courses being offered by existing universities. This task proved extremely difficult as only South Africa and Mozambique could provide the full sets of data for the period in question from central management systems. It is still not certain whether every institution per country offering engineering qualifications matching the scope of this study has been identified. A list of institutions and the numbers qualifying in 2015 is included in each country report.

Where large numbers of students were known to graduate in other countries and return to their home countries as part of their bursary contracts, they were included in the graduate inflow estimates. This data was not always forthcoming. In many instances returning graduates could not find work as their foreign qualifications were not recognised, hence the inflow figures are an estimate at best.

Graduates joining the workforce are gains but, in time, some may also be lost to the industry as noted in the discussion above, choosing to move to other sectors or to emigrate. A similar allowance has been made for losses in this group each year, but the loss has been subtracted from each year's student inflow.

GAINS – THOSE RETURNING TO THE INDUSTRY OR IMMIGRATING

A small percentage allowance was included in the overall supply estimate to allow for those:

- **Returning from other industries** who, for example, had left when construction was quiet, but returned when the industry picked up
- **Returning nationals** who, for example, may have worked on contracts abroad and returned when their contracts ended, or when local development opportunities became more attractive
- **Retirees** who were encouraged to stay on or return to the workforce for a period.

Migration was also considered as a gain when net migration was positive.

The handling of inflows from foreign countries on major contracts is very variable. Some countries insist that all engineering staff entering the country must seek temporary registration, others insist on full registration and others do not make any demands on foreign companies working locally. Hence, it could be that the workforce in some countries is higher than estimated, as there may be large groups of foreign engineering practitioners working on large contracts.

IDENTIFYING THE GAP(S)

Determining skills requirements is not a once-off exercise, but rather requires ongoing attention to the needs and a long-term view of the flow of skills. Figure 15 shows the philosophy adopted for determining the actions that need to be taken to ensure long-term supply. The elements are as follows:

- **2018 workforce** is the workforce in place at the end of 2017, shown as the orange bar, and which will reduce over the years as people leave.
- **Accumulated losses** from the 2018 workforce are shown in red, below the axis. These take retirement, mortality, those leaving the industry and net migration into account.
- **Graduates** represents those graduating who are available to enter the workplace. Only the inflow from degree courses and national diplomas are shown. Those completing post-graduate qualifications such as a BTech, Higher National Diploma or similar are not included as they do not represent additional entrants into the workforce, but rather existing capacity with post-graduate qualifications. In countries where the technologist qualification is a stand-alone qualification and does not follow the diploma, a third inflow of technologists or incorporated engineers is shown. In Angola and Mozambique, only engineers were analysed as these countries do not train technicians and technologists in a manner equivalent to the categories in this study. The model assumes a 2% increase in graduations per annum. It should be noted that in several tertiary education institutions, graduations have more than doubled since 2015. As a result, the oversupply of graduates may be higher than reflected in the flow models for some countries.
- **Accumulated gains** cover an allowance made for those returning to the industry from retirement or having been out of the local industry for a period and the net migration if positive.
- **Demand based on the 2017 GDP growth rate** is the blue dotted line, which suggests the increase that should take place to 2035 based on 2017 growth.
- **Demand based on the 2018–2023 GDP projected growth rate** is the green dotted line,

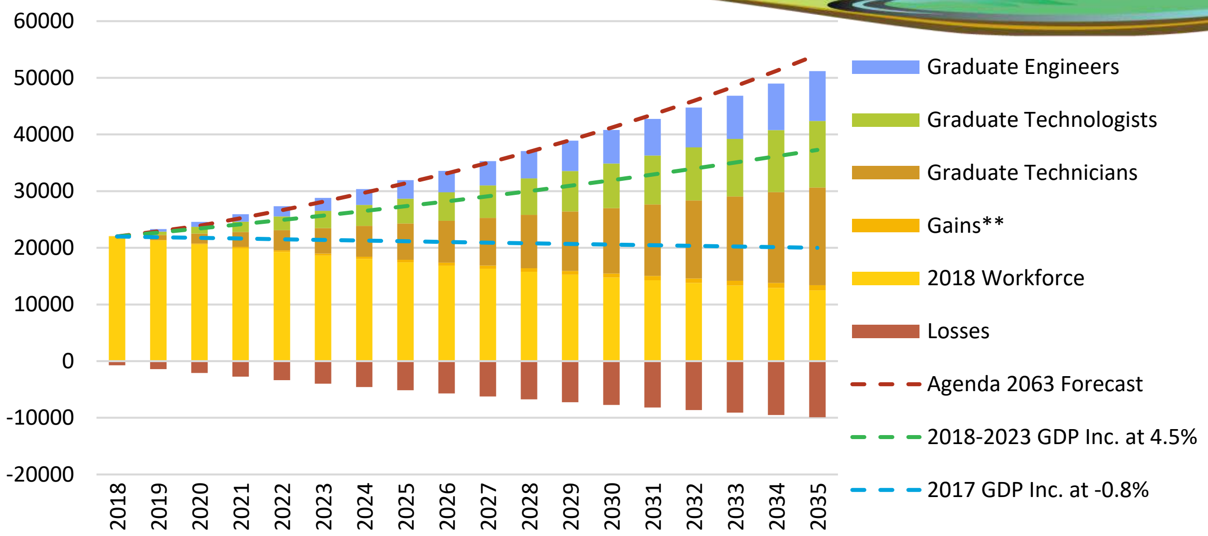


Figure 15: The projected flow of skills

which suggests the increase that should take place to 2035 based on the projected average growth for 2018–2023.

- **Demand based on the Agenda 2063 growth rate** is the red dotted line, which suggests the increase that should take place to 2035 based on the projected growth rates for Vision 2063, namely 6% to 2020 and 8% thereafter.

From Figure 15[1] it can be seen that if the graduate growth rate remains at 2%, the number of graduates coming into the system will exceed the demand, if the GDP growth is only 4.5% for the 2018-2023 period. If, however, Agenda 2063 growth can be achieved, the flow of graduates and gains will be slightly below demand by 2032.

Some countries advise that they currently require several thousand more engineering practitioners and projections should not be determined on the current low base of engineering practitioners in the workforce. Projections should rather be based on the number required at present to determine how many years it will take to achieve the desired number. Figure 16 shows a modified model assuming that the hypothetical country required 30 000 in the workforce. If increasing graduations alone are relied on, then the deficit will have been addressed by 2024 if there is no increase in demand. However, as the number required should also increase at the growth rate, the demand will only be met by 2034.

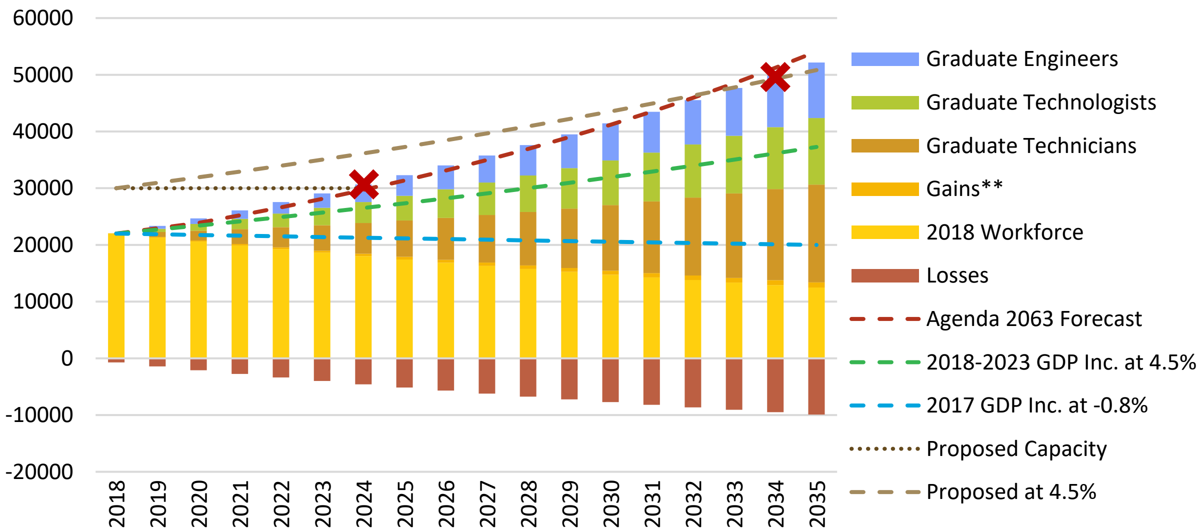


Figure 16: The projected flow of skills considering a specific target

[1] The skills flow diagram in this format was conceptualised by Allyson Lawless and Henk Langenhoven for the 2005 publication, *Numbers and Needs: Addressing imbalances in the civil engineering profession.*

If aggressive targets are set for increased graduations, then dedicated capacity for the training of incoming graduates will be required, as the ratio of junior staff to the existing workforce will be high. Few countries have achieved growth rates of the order suggested in Agenda 2063, and countries are cautioned not to develop large numbers of engineering graduates without adequate investment in projects on which to train them.

All country models have been generated assuming the current workforce as the base for projections. Should countries already have a sense of the additional numbers that they can absorb immediately, then they should superimpose the projected growth line on the existing model to determine the year by which graduations would have addressed the shortfall. If this is found to be many years in the future, consideration needs to be given to purposefully selecting and appointing expatriates to assist with current strategic and development requirements, but understudies must be identified and assigned to such experts to be coached so that they are ultimately able to take over the work carried out by expatriates.

In South Africa in the 1960s and 1970s when there was huge investment in economic infrastructure, a conscious effort was made to source expert project developers worldwide in parallel with increasing the graduation rates and training graduates on all the large projects. The engineers retiring at present are those who were absorbed and trained on the large projects. Ghana also made a conscious effort to train local graduates on the Volta Dam project in the early 1960s, after which the number of Ghanaian engineers grew steadily.

Considering the need to increase the number in industry by 3% to 5% per year for growth, and to accommodate replacement demand of some 2% to 3%, suggests that graduations should be around 5% to 8% of the workforce per year, up to a maximum of 10% in countries experiencing high growth.

In the model shown in Figure 15 the number graduating each year represents 7% of the workforce, which is a reasonable number to absorb. In some countries the model looks completely different and there are insufficient tertiary education programmes in place to address the demand. Graduation percentages of only 3-4% imply that an increase in the number of graduates is required. In these cases, until more programmes are put in place, the other options under *Gains* need to be considered, including use of retired personnel, increasing immigration and funding students to study outside the country etc.

In other countries, the percentage of graduates to workforce has reached as high as 30%. In these cases, graduates complain of not being able to find work, and industry complains of pressure to employ many more graduates than they can absorb, based on the availability of work.

Chapter 5

Research approach

To determine the numbers and needs required a detailed approach. The research harnessed several methods using qualitative and quantitative research techniques. This was necessary to triangulate input and results in order to ensure the reliability of the final numbers and recommendations.

RESEARCH PROCESS

The research phases were planned as shown in Figure 17. Although it was expected that they would be sequential, delays in receiving data, and ideas gathered after interaction with stakeholders in the first six months resulted in several changes of approach, which are discussed under the phase headings.

Figure 17: The research process

PHASE 1 – DESIGN

During this phase several activities took place.

Identifying engineering sectors

The engineering sectors in which engineering practitioners are employed needed to be identified. With the help of the South African Sector Education and Training Authorities (SETAs) responsible for the funding and developing of skills, it was possible, by analysing their data, to determine the many sectors in which engineering practitioners were employed. Although they are found in the financial sector and other sectors not directly linked to engineering, the majority of engineering practitioners were employed in agriculture; construction; energy, gas and water; manufacturing; mining; and the transport and telecommunications sectors. These sectors were used as the major themes for research, although tourism and the Blue Economy were later added for the island states.

Identifying stakeholders

It was necessary to decide on the major stakeholders with whom to engage. Voluntary associations, registering bodies and major employers in both the public and private sectors were recognised as being important, and a substantial database for the entire region was developed.

Identifying major datasets

Over and above the datasets to be collected from stakeholders, many national sets of data needed to be accessed. These included labour force surveys, economic data, migration, and mortality and age data to determine gains to and losses from the workforce. It was also necessary to understand the engineering services currently supplied, the targets to be achieved and the projects planned. Sources of graduation data were also investigated, but very little data was available in central systems and it needed to be accessed from each tertiary education institution offering engineering qualifications. Data from voluntary associations and registering bodies was also requested, but data structures varied considerably.

Designing questionnaires

Once an understanding of the sectors to be interrogated and the data available had been established, questionnaires in English, French and Portuguese were developed to elicit further data. These covered:

- **Tertiary education institutions** to offer graduation data, gender and nationality of students, details of the qualifications offered and information on staffing and vacancies
- **Organisations** to understand the number employed per sector, training offered, vacancies, disciplines, categories, gender, education, nationalities and growth planned
- **Voluntary Associations (VAs):** to understand the numbers, categories, gender, ages, nationalities, disciplines, and, where available, country of study and qualifications of members

- **Registering Bodies (RBs)** to understand the numbers, categories, gender, ages, nationalities and disciplines of those registered.

In some instances, the place of work was available from VAs and RBs, which was useful to get a sense of the range of sectors in which people worked and the trends in terms of registration, and membership of VAs per sector. In some instances, data from VAs and RBs also offered insight into where people had studied, with many older practitioners having studied abroad.

Results from the organisation questionnaire provided excellent triangulation in terms of tertiary education, as employers were asked to list the institutions at which most of their staff had studied, and also gave insight into in-house training taking place, mostly in the large organisations.

Developing a communication platform

To communicate with all stakeholders, establish more contacts and gather input, the website www.numbersandneeds.co.za was set up. It was also used to share information, documents and presentations, and to involve stakeholders in online surveys.

PHASE 2 – RESEARCH

The detailed research covered a long period of desktop research; analysing existing datasets; field research, including in-depth interviews with relevant stakeholders; and presentations and discussions at major industry workshops. The research activities are outlined below:

Desktop research

During the desktop research phase, data was gathered from many sources. Activities included:

- Reviewing SADC strategy documents and plans
- Reviewing national development plans, policies and strategies
- Searching for and reviewing studies per sector, per country and reports covering trends in the SADC region and Africa
- Reviewing the annual reports of ministries, utilities, major employers, VAs and registering bodies
- Reviewing economic trends and forecasts
- Searching for and reviewing education data and reports per country and in the region.

Analysing existing datasets

This covered the analysis of data sourced in Phase 1. Sadly, many labour force surveys were very out of date and did not drill down to the occupation levels required. When occupation data was available, it generally did not agree with the actual membership data received from various organisations, and little reliance could be placed on the data.

Migration proved equally difficult to determine as data is limited or not available and, where available, does not drill down to professional and specifically engineering level. Using the United Nations Population Division statistics and superimposing the views from various studies, estimates of the movement of professionals were determined.

The studies used to determine the movement of professionals included the *Southern African Migration Programme* report in which it was estimated that 10% of migrants from the SADC region and 25% from the rest of Africa had post-secondary qualifications and could be considered as professionals.

With regard to immigration and emigration, other research exercises suggest percentages which, when combined, agree roughly with the overall migration percentages estimated in the above study. They indicate that, on average, around 4% of those who immigrate to developing countries are professionals.

Sources on emigration indicate that over the period 1990 to 2009 around 16% of those who emigrated were professionals. Since 2010, 17.1% of those who emigrated from Africa had tertiary qualifications and since 2013, this has increased to 18.6%.

National and international datasets were interrogated for demographic and economic data which, when combined with the country sector studies, offered a sense of the challenges each country was facing in terms of funding and possible development. Using this information, draft reports, presentations and questions were prepared for engagement with each country.

Stakeholder engagement

All countries were visited, and many calls, Skype sessions and emails took place before and after the meetings to collect as much data and gain as much insight as possible.

During country visits, meetings were held with most infrastructure ministries, major employers, education institutions, VAs, RBs, consulting, manufacturing and mining associations, and contractor registering councils, where they existed.

As part of the preparation for each trip and meeting, the SADC introductory letter, some background information and the appropriate questionnaire were sent to allow stakeholders time to prepare for the discussions. In some cases, completed questionnaires were received at the time of meetings, and in other cases, they were received later.

Some stakeholders were diligent about providing the detailed data, but estimates discussed at the time of meetings have been used to develop the overall models where data was not forthcoming. In many instances, the questionnaires were not completed in full, but totals were supplied.

Many different approaches were eventually used to make contact and set up the country visits. No single approach proved to be more effective than another. The final results depended on the capabilities and willingness of the organisations that participated in the meetings and workshops. In the DRC, Angola and Tanzania, the South African Embassy assisted with making initial contacts and in the case of the latter two, the local foreign office became involved. In other countries, the SADC focal point coordinator either assisted with the names of contacts in each sector or made the appointments, while in other countries, it was necessary to contact each institution and department directly to set up appointments. The latter was the case in ten countries. In these instances, the RBs and VAs were very helpful in providing contacts.

Sadly, there are no countries from which a full set of data, covering all sectors, Professional Bodies Institutions (PBs) and tertiary education was obtained.

Workshops and conferences

The research team has attended and presented at many workshops and conferences. The presentation outlined the project and data required, and delegates were asked to engage with researchers during breaks or to download questionnaires from the website and there were many follow-up emails.

Where the nature of the event allowed audience participation, valuable input was received, and consensus was reached on various topics. Workshops or conferences in the following countries were addressed:

- Angola
- DRC
- Eswatini
- Ethiopia (attended by many SADC countries)
- Lesotho
- Malawi
- Namibia
- Seychelles
- South Africa (several local, regional and African conferences)
- Zambia.

Data gathering

The gathering of data proved to be the most challenging activity. Although several sets of data are prepared each year by national statistics departments, as outlined under Phase 1 and 2, data relating to tertiary education and employment in specific sectors, down to engineering practitioner level, is not available Much engagement was therefore necessary. Engineering professionals involved in water, energy and transport were generally to be found in the public sector. Information for the other sectors needed to be established by engaging with the private sector.

- **Tertiary education:** Centrally managed graduation data from ministries of education was only available from South Africa (2000 to present), Angola (2013 to 2015), Mozambique (2005 to 2015, although 2015 appeared to be incomplete) and Madagascar (2014). The Ministère de l'Enseignement Supérieur et Universitaire in the DRC gathered data for the study for the period 2013 to 2017. In all other countries, it was necessary to contact each tertiary institution offering engineering qualifications. The study commenced in the first half of 2017, when education data had only been audited and published officially to the end of 2015, hence the decision to gather data from 2005 to 2015. However, with the difficulty in collecting data, the project took substantially longer than expected, but time did not permit contacting all tertiary institutions again to gather data to 2017. Anecdotally, graduations have continued to increase since 2015.
- **Professional bodies (PBs):** While most countries had VAs, several countries did not have registering bodies. Most countries made data available from their databases, but some did not have comprehensive data. For instance, some institutions did not have gender information, while others did not have nationality, age or discipline data. Data was received from all countries, but in some cases the detail available or the sample size was inadequate for the data to be meaningful.
- **The public sector:** It was hoped that full sets of data from infrastructure ministries would be available. However, the inadequacy of data structures or, in some cases, lack of cooperation,

resulted in gaps in the data in all countries. Profiles of neighbouring countries of similar sizes and economic activities were used to estimate numbers.

- **Agriculture:** Very few countries have VAs in this sector, making it difficult to determine the number of agricultural engineering practitioners. Where a sense of the number was available, it was still not possible to determine how many were working in agriculture and how many had moved to other sectors. Furthermore, many other disciplines are involved in the sector, as discussed in Chapter 2. The number shown in most countries is a rough estimate at best. In the French-speaking and Portuguese-speaking countries, the training of agricultural engineers includes substantially more agricultural science than in English-speaking countries. There are large numbers of agronomic engineers covering animal husbandry and nutrition; crop production; plant, soil, environmental protection and water resource management; horticulture; and agricultural management and marketing. Data from agronomist VAs in these countries was available.
- **Construction:** In most countries it is a requirement for contractors to register with a construction council or with the Ministry of Public Works or similar, most of which made contractor data available, although few could estimate the number of engineering practitioners. Contractors are graded according to their capabilities and experience. Considering the criteria and the number of contractors per grade, it was possible in many countries to estimate the number of engineering practitioners in the sector. However, contractors do not always retain the number stated once they have been registered, hence the numbers may be overstated in some countries.
- **Consulting:** Many associations of consulting engineers were able to make data available or to estimate the number of engineering practitioners based on their member organisations. In those countries with no associations, estimates were developed when engaging with the major consulting firms.
- **Manufacturing:** Manufacturing data was the most difficult of all to gather, as associations of manufacturing in each country were focused on providing corporate, marketing and export support to their member companies. Information relating to engineers is not collected by any of these organisations. In some countries, major manufacturing companies such as breweries, confectioners and food manufacturers provided details on their considerable engineering workforces and assisted with estimates of the numbers likely to be employed by manufacturers. Values are therefore an estimate at best. In South Africa, data from the SETAs, the QLFS and online surveys allowed a slightly more accurate estimate to be determined, but it is still only an estimate.
- **Mining:** The Chambers of Mines in each country represent the interests of their member companies and, as with manufacturing, they do not collect information relating to engineers. In some countries, ministries provided data and in other countries, mining houses provided their data. Numbers were estimated using the models provided and considering the type and volume of each commodity extracted. Once again, this represents an estimate only.

It must be emphasised that the data presented throughout are only estimates, some more accurate than others, due to the paucity of data. This study has certainly served to highlight the lack of, and inconsistency of, statistics and indicators relating to engineering practitioners.

An allowance of 5% has been made for *Miscellaneous* to cover those engineers working in the financial and insurance sectors, advising on infrastructure developments, investments, loans, risks, etc., and those working in other sectors requiring engineering input or knowledge.

Many engineers also work for NGOs involved in water, sanitation, health, safety, education and community development programmes, and professional bodies, to name a few. For this reason, a further 5% allowance has been made for engineering practitioners working in the many NGOs distributed throughout the region. The percentage has been increased slightly in countries with limited or failing social infrastructure, such as Madagascar, and has been reduced where lower levels of NGO support are required.

PHASE 3 – ANALYSIS

Analysis and interpretation of data is the interesting part of any research project. Seeing numbers triangulate, views agree and trends emerge is most gratifying.

Analysing data

Analysing the data received was a critical activity. In many instances, incomplete submissions required follow-up calls and discussions to ensure that the data received included the range of variables that needed to be analysed. Often, data included

information on operators and craft- or tradespeople, which had to be removed. In other instances, variables were missing, requiring further follow-up. As outlined above, many institutions have never built complete sets of data. This required follow-up discussions to estimate values.

Interpreting trends

From an early stage trends began to emerge. To ensure that trends were being correctly interpreted, additional desktop research was carried out and stakeholders were contacted to confirm the research teams' interpretation of the trends or to offer additional insight. Gaps emerged from which many recommendations flowed.

Developing the report

Developing the report was a long, slow process. A report for each country was prepared under specific headings to ensure consistency of the reports. This approach led the research team to review all reports several times as new topics and ideas emerged in specific countries which were found to be relevant to all. Once the country reports had reached some degree of maturity, the overview document and overall findings were developed.

PHASE 4 – REVIEW

This phase covered the gathering of outstanding data and verifying the data and views expressed.

Stakeholder input

Once in their draft form, country reports were issued to those stakeholders with whom researchers had engaged for their input on the validity and relevance of the content, and in particular on the recommendations. Once the reports were nearing completion, stakeholders were able to gain a better feel of the intention of the study and some countries offered valuable further input.

Validation workshops and engagements

Two validation workshops were held, one in June 2018 and a further workshop in November 2018. Eswatini, Mozambique, Namibia, South Africa, Tanzania, Zambia and Zimbabwe participated in one or other of the workshops. The intention was for countries to understand the approach taken, review the reports to date and return to their countries to test the accuracy and acceptability of the report, and to collect missing data. Two DRC nationals living in South Africa who attended the second workshop to offer their views also committed to chasing up more data and soliciting views. The Association of Engineers of DRC Origin in South Africa (AEDOSA) later gave input.

Outside of the validation workshops, the Botswana report was commented on by the Botswana Institution of Engineers (BIE) and the Engineers Registration Board in September 2018, and the Angola report by the Ordem dos Engenheiros de Angola. The Seychelles report was finalised with the help of the National Institute for Science, Technology and Innovation (NISTI) in late 2018.

The Malawi report was presented to a delegation from Malawi, consisting of representatives from the Ministry of Transport and Public Works, the National Construction Industry Council and members from academia in December 2018, after which corrections were received.

Input or edited reports from the remaining countries were received from individuals or the professional bodies in those countries.

Receive final data

After the workshops many missing pieces of data were received and consolidated into the reports. Participants had similar challenges accessing data to the research team, hence validation workshops served only to enhance the reports to some extent, rather than ensure their completeness.

PHASE 5 – FINALISE THE REPORT

The final phase covered consolidating the final input, editing the document, finalising the design and presenting and handing it over to the client.

DATASETS USED

Data was compiled from many sources. The data continues to change as annual reports are published and more up-to-date research is carried out. The references therefore do not include each URL visited, as many that were visited in early 2017 had already been replaced with later information, named differently, by the end of 2018. The reader is referred to the sites listed below for the latest information. Specific references will be made available on request. Please email info@numbersandneeds.co.za with your request.

Where relevant country and sector-specific research was available, these references are given under the section *Sources of Information* in each country report.

DEMOGRAPHICS AND THE ECONOMY

As much demographic data as possible was extracted from the *SADC Statistical Yearbook 2015*. Where information required was not available, the following sites or sources were used:

- AfDB – Africa Development Bank
- *Africa Economic Outlook*
- *Africa on the Rise*
- African Advisor
- African Business Communities
- *African Business Review*
- *African Review*
- African Volunteer.net
- Democracy Africa.org
- Export.gov
- IMF – International Monetary Fund
- Index Mundi
- International Labour Organisation
- *Knoema's World Data Atlas*
- Labour Force and Household Surveys carried out by national statistical departments
- Mbendi
- Mongabay
- *Nations Encyclopaedia*
- PwC reports
- Southern-African German Chamber of Commerce and Industry
- Statista
- *The CIA World Factbook*
- *The World Folio*
- Top 10 Exports
- *Trading Economics*
- TRALAC – Trade Law Centre
- UNICEF – United Nations International Children's Emergency Fund
- *World Atlas*
- World Bank Reports
- *World Finance*
- *World Population Review*
- World's Top Exports.

AGRICULTURE

- ACTIF – Cotton Africa, African Cotton & Textile Industries Federation
- *Africa Essays*
- AgDevCo – Investment and project developers
- AQUASTAT – water database of the FAO
- CAADP – Comprehensive Africa Agriculture Development Programme
- FAO – Food and Agriculture Organization of the United Nations
- Global Forest Watch
- Global Partnership
- Global Yield Gap Atlas
- IAEA – International Atomic Energy Agency
- ICID – International Commission on Irrigation and Drainage
- IFAD – International Fund for Agricultural Development
- *New Agriculturist*
- Trading Economics
- UNDP – United Nations Development Programme
- United Nations Sustainable Development Goals
- USAID – United States Agency for International Development

MINING

- AZO Mining Reports
- Chambers of Mines reports per country
- EITI – Extractive Industries Transparency Index Reports
- *Mining Review*
- Mining.com
- NASA Earth Observatory
- Rigzone.com
- US Geological Survey

MANUFACTURING

The United National Industrial Development Organisation (UNIDO) holds the most comprehensive set of data on manufacturing and publishes the *International Yearbook of Industrial Statistics* annually, covering select countries in each edition. Where available, data from national banks is the most accurate, but is generally considered to be confidential at the level of manufacturing subsectors.

The Yellow Pages or equivalent were consulted in each country to gain a sense of the type and range of manufacturing industries, in the absence of comprehensive research reports. Where manufacturing associations or the Chamber of Commerce carried out detailed research, these reports were used.

ENERGY, GAS AND WATER

- AMCOW – African Ministers' Council on Water
- EIA – US Energy Information Administration
- Energy for Africa
- SE4ALL – Sustainable Energy for All
- USEA – United States Energy Association
- *ESI Africa* (Africa's Power Journal)
- SADC regional and country energy master plans
- SADC regional and country water master plans
- Energy-pedia.com
- WASHwatch – a site monitoring the progress with water, sanitation and hygiene facilities

TRANSPORT AND COMMUNICATIONS

- *Africa Ports*
- *African Telecoms News*

- Cross Border Road Transport Agency country profile reports
- FTTH Council Africa reports
- ITU – International Telecommunications Union
- Liquid Telecom
- Logistics Cluster
- Ports of Entry
- *Railways Africa*
- SADC regional and country communications and transport master plans
- *Transport World Africa*
- WRA – World Road Association (also referred to as PIARC – Permanent International Association of Road Congresses)

CONSTRUCTION AND HOUSING

- CAHF – Centre for Affordable Housing Finance Africa
- Commonwealth Local Government Forum information
- *Construction Review*
- PIDA – Programme for Infrastructure Development in Africa
- SADC regional and country infrastructure master plans
- UN–Habitat

EDUCATION

- HEMIS – Higher Education Management Information System (South Africa)
- SACMEQ – The Southern and Eastern Africa Consortium for Monitoring Educational Quality
- SARUA – Southern African Regional Universities Association
- UIS – UNESCO Institute for Statistics for student mobility
- UNESCO literacy and enrolment data
- *University World News*

GENERAL

A range of reports are available from several international players. These include:

- NEPAD – New Partnership for Africa's Development policies and reports
- Deloitte country and sector reviews
- PwC sector reviews
- UNESCO: National Commission reports covering all GPD sectors of interest
- MONGABAY: A non-profit provider of conservation and environmental science news.

COUNTRY METRICS

Table 1 in each country report covers a range of metrics to give a sense of the demographics, services and
regional or international indicators. Table 8 shows the sources used for each set of data.

SADC DATA

Until 2015 SADC annually published a comprehensive set of data covering country demographics, economics and services, etc. in the *Statistical Yearbook.* The detailed spreadsheets and written reports per year are available on the SADC website. Budgets have not been available to continue with detailed research annually. Since 2016, only SADC *Selected Economic and Social Indicator* reports have been published. The research team was advised to use the *2015 Statistical Yearbook* as the most

Table 8: Sources of data for country metrics

Population	
Total	*SADC Selected Indicators 2017*
Urban and rural split	*SADC Statistical Yearbook 2015**1*
Poverty, HIV, Unemployment	
Below the international poverty line	World Bank
HIV-positive	World Health Organization 2017
Unemployment	*SADC Statistical Yearbook 2015**2*
Human Development Index	*SADC Statistical Yearbook 2015*
Electricity	
Production kWh	*CIA World Factbook*
Consumption kWh	*CIA World Factbook*
Airports and Ports	
Airports – paved and unpaved	*CIA World Factbook*
Ports	Individual references
Kilometres of	
Roads, rail, pipelines and waterways	*CIA World Factbook**3*
Africa Infrastructure Development Index	African Development Bank 2018
Services	
Access to safe drinking water	*SADC Statistical Yearbook 2015**4*
Access to improved sanitation	*SADC Statistical Yearbook 2015**4*
Access to electricity	*CIA World Factbook**5*
Telephones	ITU 2016*6
Mobile phones	ITU 2016*6
Internet users	ITU 2016*6

*1. Except Seychelles (CIA World Factbook)
*2. Except Mozambique (CIA World Factbook)
*3. Except Botswana (Economics Africa), Mozambique and Tanzania (Road data from Roads Authorities)
*4. Except the Seychelles (Own data)
*5. Except Mauritius (SADC 2015)
*6. Except DRC (2014) and Seychelles (2018)

consistent and reliable source of data for as many of the required metrics as possible.

INDICATORS

Several indicators have been developed to compare the status of many variables per country. Three indicators were considered, as discussed below.

International Poverty Line

Poverty lines serve as a measure of the minimum level of income considered adequate per country to satisfy the basic need for food, water, clothing and shelter. In 2015, the World Bank set the international poverty line as US$1.90 PPP (purchasing power parity). National poverty lines vary according to costs in each country and are usually published with country census data. The values suggested by the World Bank for different income countries are:

- International poverty line – US$1.90 PPP
- Lower middle income class poverty line – US$3.20 PPP
- Upper middle income class poverty line – US$5.50 PPP.

For purposes of comparison, the international poverty line has been used for all countries in this study. This gives a sense of the extent of poverty, and the investment and development required to stimulate growth and address poverty.

HIV/AIDS prevalence rate

The HIV/AIDs prevalence rate is the percentage of the total number of individuals per population infected with HIV/AIDS, while the incidence rate is the rate of new infections per reporting period. The total number infected as reported by the World Health Organisation in 2017 and the population of each country as reported in the 2017 SADC Selected Indicators report were used to calculate the percentage.

Human Development Index

The Human Development Index, as determined by the United Nations Development Programme (UNDP) is a measure of life expectancy, education and per capita income. The index will result in similar rankings to the international poverty line, but will vary where the standard of education and/or health services is higher than in countries with similar infrastructure and economic indicators.

Africa Infrastructure Development Index

The African Infrastructure Development Index (AIDI) as determined by the African Development Bank, is a measure of infrastructure development. It considers the extent and condition of water, sanitation, electricity, transport and ICT infrastructure. It is explained in more detail in Chapter 6.

TIMEFRAMES

The project commenced in April 2017 and was expected to take 18 months. Phase 1 to 3 were to be completed during 2017, but due to lack of data and poor responses it became necessary to spend time in every country. Most country visits took place from January to September 2018 and the final validation meeting took place in November 2018. Unless otherwise noted, data and views quoted relate to 2018.

Chapter 6

Sector performance

The development of significant services sectors is considered critical for countries to transition from low- and medium-income economies to high-income economies. Strong service sectors are not possible without developing the engineering-related contributors to the economy. Resources in each SADC country are plentiful and therefore the potential exists to increase secondary and tertiary production, but this requires investment and engineering capacity.

The contribution and status of each engineering sector is outlined below.

AGRICULTURE

Table 9 shows the contribution of agriculture to the economy in each country; the estimated percentage of the population involved in agriculture; and the area of arable and irrigated land. Details on the cultivated and irrigable potential were not available from all countries. However, from information available, it was evident that there is significant potential in many countries to expand production.

The percentage of rural communities eking out a living is alarming and does little to encourage people to remain on the land. Given the large percentage of young people, this must be addressed to prevent mass migration to the cities which is unsustainable. The need for good local education, health and basic services is critical and extensive agricultural support for smallholders and rural communities is required.

Although it was not part of this study, it was evident that in many countries, agricultural extension capacity has declined, and where young people are being trained, they have had limited hands-on experience, hence their advice is not valued by mature farmers. Community engagement with experts who can demonstrate the value of change is essential before new approaches such as diversification, conservation agriculture or cooperative farming will be adopted. Where comprehensive extension support has been in place, there are many success stories of improved output using improved seed, fertilisers, controlled watering and other techniques.

To expand the areas that families can farm effectively, the introduction of small-scale mechanisation has proved successful in India and China. Mauritius is following their example in the quest to become self-sufficient in food production – the Ministry of Agro-Industry and Food Security makes equipment available to farmers who cannot afford the capital cost.

Many innovations require engineering skills or input of some sort. In many countries, getting produce to markets is cited as a challenge due to the poor condition of the roads. There are also limited post-harvest facilities for processing, packing and storing excess crops. Transport network development plans are normally based on the needs of the mining and manufacturing sectors. Expanding outlet opportunities for agricultural production and

Table 9: Agricultural metrics

(Malawi GDP 2012, Agricultural data from Trading Economics)

COUNTRY	Contribution to GDP 2015 (US$ million)	Agricultural % of GDP 2015	% contribution to engineering GDP	% relying on agriculture	Arable 1000 ha	Permanent cropland 1000 ha	Land equipped for Irrigated 1000 ha	Smallholder ave size ha	Country area 1000 ha
Angola	$11 184	9.9%	17.4%	66%	4 900	332	86	1	124 670
Botswana	$313	2.4%	5.7%	70%	399	2	2	5	58 173
DRC	$6 895	19.9%	26.9%	70%	7 100	931	11	2	234 486
Eswatini	$301	8.2%	15.8%	70%	175	15	50	1	1 736
Lesotho	$113	5.6%	12.7%	66%	272	5	3	3	3 036
Madagascar	$2 042	24.9%	36.4%	78%	3 500	628	1 086	1	58 704
Malawi	$1 532	28.3%	57.4%	80%	3 800	175	104	1	11 848
Mauritius	$362	3.5%	9.8%	8%	74	4	20	0	204
Mozambique	$3 464	24.5%	43.1%	73%	5 650	305	118	5	79 938
Namibia	$697	6.6%	15.5%	70%	800	9	8	2-7	82 429
Seychelles	$31	2.7%	7.9%	4%	3	1.4	0.3	1	46
South Africa	$6 672	2.4%	5.7%	17%	12 500	415	1 601	1	121 909
Tanzania	$13 110	31.1%	48.7%	67%	13 500	2302	184	0.2-2	94 730
Zambia	$1 060	5.3%	10.9%	56%	3 800	36	156	5	75 261
Zimbabwe	$1 666	13.3%	25.0%	70%	4 000	101	174	5-10	39 076

growing sustainable rural communities should be factored into these plans.

MINING AND QUARRYING

When one considers mineral wealth, the region is a treasure trove. Angola is the fourteenth-largest oil producer in the world and the second-largest in Africa, after Nigeria. The DRC has the second-largest reserves of diamonds in the world, with Botswana in fourth position and South Africa in fifth. The DRC also holds the world's largest reserves of cobalt, by a large volume, with Zambia in fourth position and Madagascar in eighth position. South Africa has the world's largest reserves of manganese, platinum (with Zimbabwe in third position) and chrome. Namibia has the fourth-largest reserves of uranium in the world, with South Africa in fifth position. Zimbabwe has the eighth-largest reserves of lithium and Tanzania is the only country in which tanzanite is found. Lesotho produces the largest diamonds in the world and the discovery and development of the gasfields off the shore of Mozambique will change the fortunes of that country. This leaves only the Seychelles and Mauritius with no mineral wealth, and Malawi with limited reserves.

The mining contribution to GDP varies considerably per country, depending not only on the mineral wealth of the country, but also on the general state of the economic infrastructure, the economy and investment levels. The GDP contributions and main activities are shown in Table 10. Several countries, namely Angola, Botswana and the DRC, are highly dependent on their income from minerals and need considerable diversification to protect them from the shocks experienced when commodity prices and associated demand drop. In several other countries, the mining GDP exceeds 15% of the engineering-related GDP earners, indicating the need for significant engineering skills in this sector.

The lack of infrastructure restricts the development of vast mining potential in many countries. Power is essential for mining and particularly smelting, as is a good transport network. In Mozambique, for instance, the mining of coal from the Tete area only became viable once the SENA railway line had been constructed.

As discussed in Chapter 1, investment in and the use of cutting-edge technology is essential for the mining sector to continue to be competitive. The number of countries which nationalised their mines to access the capital, and subsequently experienced significant economic downturns, should ring warning bells for others considering following this practice. Imposing

Table 10: Mining commodities and potential

*(*Malawi GDP data 2012)*

COUNTRY	Contribution to GDP 2015 (US$ million)	Mining % of GDP 2015	% contribution to engineering GDP	KEY COMMODITIES (Output could generally increase with investment)	ADDITIONAL POTENTIAL (Subject to investment and infrastructure)
Angola	$26 512	23.5%	41.3%	Oil, gas, diamonds, iron	Gold, copper
Botswana	$2 625	20.2%	47.8%	Diamonds, coal, nickel	Gold, copper, iron
DRC	$6 647	19.1%	25.9%	Oil, copper, cobalt, diamonds, zinc	Lithium, niobium, manganese, zinc, cobalt, iron, cassiterite, gold
Eswatini	$6	0.2%	0.3%	Coal	Iron, gold, diamonds
Lesotho	$167	8.3%	18.8%	Diamonds	Uranium, coal, iron
Madagascar	$20	0.2%	0.4%	Nickel, cobalt, ilmenite, chrome, sapphire	Coal, bauxite, oil
Malawi*	$68	1.2%	2.5%	Uranium, coal, ruby, sapphire	Bauxite, graphite and heavy minerals
Mauritius	$25	0.2%	0.7%	Quarrying	-
Mozambique	$772	5.5%	9.6%	Tantalum, ilmenite, zircon, coal, gas	Gold, graphite, iron
Namibia	$1 428	13.5%	31.9%	Diamonds, gold, uranium, zinc, lead, copper, iron	
Seychelles	-	-	-	-	-
South Africa	$22 431	8.0%	19.2%	Gold, PGMs, iron ore, chrome, coal, silver, diamonds, uranium	
Tanzania	$1 821	4.3%	6.8%	Gold, uranium, gas, nickel, copper, diamonds, tanzanite	Iron
Zambia	$2 697	13.4%	27.9%	Copper, cobalt, coal, uranium	
Zimbabwe	$1 098	8.8%	16.5%	PGMs, gold, chrome, coal, iron, nickel	

high levies on the sector is also detrimental to national economies in the long term, as mining operations become unviable, or unattractive to investors. The multiplier effects of the sector are considerable given not only the beneficiation and manufacturing opportunities, but also the economic and employment opportunities in mining towns in providing goods and services to local communities.

Policies that are a deterrent in many countries need to be reviewed to attract investors and grow the potential that exists. With the mineral wealth in the region, no country should be struggling with a failing economy, rising debt, poverty and hunger.

MANUFACTURING

Although most countries proclaim themselves not to be manufacturing countries, there are many basic products manufactured in each country. Typically, food processing and the production of soft drinks and brewing take place, all of which require engineering skills. Due to the high cost of freight for large-volume products, plastic products tend to be made in each country, even if the raw material needs to be imported. Likewise, paper and packaging products, paints, cleaning materials and other chemicals are generally manufactured locally. Quarrying and the production of associated building materials are also local activities.

Many countries have created manufacturing opportunities based on their unique or local resources, which, although small in some cases, require highly specialised skills. Table 11 shows that manufacturing contributes 10% or more to the GDP in almost half the countries, and represents more than 20% of the engineering GDP in nine of the SADC countries. The climate in many countries lends itself to growing sugar, fruit, cotton, tobacco and spices, each of which offer manufacturing opportunities as listed under Potential and Growing Markets.

Currently heavy and advanced manufacturing are generally limited to a few countries but have the potential to be developed in many countries. Moving from low-tech industries which largely require artisanal skills to high-tech will require the range of engineering skills. These include, in the main, chemical, electrical, industrial and mechanical engineers, and these must be available in adequate numbers.

The absence of engineering associations in manufacturing made is impossible to determine accurate engineering numbers and needs. Another approach to understanding the mix required, would be to study the manufacturing value added (MVA) per industry, but MVA data was not readily available in detail in many countries. Descriptions of the range of manufacturing activities have therefore been included in each country report to create awareness of the need to continue developing engineering disciplines relevant to each industry. The numbers estimated for manufacturing must be taken as rough estimates at best.

Table 11: Manufacturing metrics

*(*Malawi GDP data 2012)*

COUNTRY	Contribution to GDP 2017 (US$ million)	Manufacturing % of GDP 2015	% contribution to engineering GDP	POTENTIAL AND GROWING MARKETS
Angola	$6 015	5.3%	9.4%	Fuels, fish processing, coffee, alcoholic beverages
Botswana	$824	6.3%	15.0%	Diamond cutting, batteries, meat processing, leather goods
DRC	$6 154	17.7%	24.0%	Quinine, cocoa, coffee
Eswatini	$1 259	34.3%	66.0%	Sugar, soft drink concentrates, wood pulp
Lesotho	$214	10.6%	24.1%	Textiles and clothing
Madagascar	$1 133	13.8%	20.2%	Coffee, tea, spices, fish, textiles, perfumes
Malawi*	$422	7.8%	15.8%	Cotton, tobacco, sugar
Mauritius	$1 526	14.7%	41.3%	Textiles and clothing, sugar, medical equipment, electronics, fish, coffee, tea, spices
Mozambique	$1 379	9.8%	17.2%	Aluminium, tobacco, nuts, fish processing
Namibia	$945	8.9%	21.1%	Armoured vehicles, fish and meat processing
Seychelles	$73	6.4%	19.0%	Fish processing
South Africa	$37 215	13.2%	31.8%	Vehicles, machinery, weapons, explosives, aluminium, electronics, wines, spirits, rooibos, other beverages
Tanzania	$2 373	5.6%	8.8%	Coffee, tea, fish processing, cotton, tobacco, safari vehicles
Zambia	$1 600	7.9%	16.5%	Sugar, tobacco
Zimbabwe	$1 413	11.3%	21.2%	Tobacco, meat processing, sugar

ENERGY, GAS AND WATER

Without an adequate supply of energy and clean water, beneficiation and industrialisation are not possible. Poor sanitation and unsafe water are major health hazards and cost countries significant amounts in terms of health care. The time involved in walking to collect water reduces productive time available for cottage industries or farming activities.

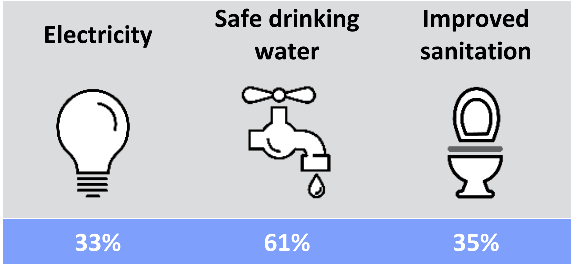


Figure 18: Average percentage with access to services

(2011 to 2016, depending on data availability)

Figure 18 shows the overall percentage access per service achieved in the region up to 2015, while Table 12 shows that many countries still have a long way to go to achieve universal access to these services. (It should be noted that access data for a set year is not available – the data is based on the latest information available from 2013, 2014 or 2015.)

The whole process of long-term planning, prioritising projects, scoping, raising funds, designing, developing and implementing solutions to increase capacity, or to rehabilitate neglected infrastructure, requires significant engineering capacity. In most government departments throughout the region, vacancy levels are high or non-technical staff occupy technical posts. In some countries there is a moratorium on employing staff in public sector structures, which is resulting in capacity declining as employees leave the sector.

Extremely ambitious targets have been set to achieve universal access, many of them requiring the development of large bulk capacity and substantial networks. If these targets are indeed to be achieved, it is critical that capacity requirements for maintenance teams should be determined, and that the education, training and expansion of maintenance teams should commence in the short term to ensure that there is capacity to operate and maintain new infrastructure.

Some governments suggested that they would be outsourcing their maintenance to subcontractors. Expansion and training of the subcontracting network will need to be managed to ensure that subcontractors are adequately equipped, and have appropriate staff, trained to the standard required by for each service.

Table 12: Access to basic services

(2011 to 2016, depending on data availability)

COUNTRY	ACCESS TO SAFE WATER	ACCESS TO IMPROVED SANITATION	ACCESS TO ELECTRICITY	YEAR TO ACHIEVE UNIVERSAL ACCESS		
				SAFE DRINKING WATER	IMPROVED SANITATION	ELECTRICITY
Angola	44%	60%	30%	>2030	>2030	2030
Botswana	97%	74%	66%	2030	2030	2030
DRC	46%	31%	9%	>2030	>2030	2050
Eswatini	74%	68%	27%	2022	2022	2025
Lesotho	78%	26%	17%	2030	2030	>2030
Madagascar	52%	12%	15%	None set	None set	2040
Malawi	87%	55%	9%	2025	2030	>2030
Mauritius	100%	100%	99%	-	-	2020
Mozambique	51%	27%	39%	2030	2030	2030
Namibia	92%	32%	32%	2020	>2030	2030
Seychelles	96%	98%	97%	2030	2030	2030
South Africa	91%	80%	85%	2030	2030	2030
Tanzania	55%	14%	24%	2030	2030	>2030
Zambia	68%	25%	26%	2030	2030	>2030
Zimbabwe	76%	62%	40%	2030	2030	2030

TRANSPORT AND COMMUNICATIONS

Good transport and communication networks are essential to grow any economy.

TRANSPORT

Due to the size of many countries, an extensive road and rail network, in good condition, is required. Furthermore, to ensure the flow of produce, material and manufactured goods to address food security and grow economies, corridors connecting countries are required.

Data relating to the lengths of rail and paved and unpaved roads are shown in Table 13. Many railway lines and paved roads are in poor condition and many unpaved roads serve as the main access to markets, taking days instead of hours to traverse. Major upgrades to roads and rail are required to achieve the smooth flow envisaged.

Table 13: Lengths of rail and road network

COUNTRY	RAIL LENGTH	PAVED ROAD	UNPAVED ROAD	YEAR
Angola	2 852	5 349	46 080	2001
Botswana	888	7 892	20 260	2011
DRC	4 007	2 794	150 703	2004
Eswatini	301	1 078	2 516	2002
Lesotho	1.6	1 069	4 871	2011
Madagascar	836	6 103	31 373	2010
Malawi	767	4074	11378	2015
Mauritius	-	2 379	49	2015
Mozambique	4 787	7 365	23 718	2018
Namibia	2 628	6 387	37751	2010
Seychelles	-	514	12	2015
South Africa	20 986	158 124	591 876	2014
Tanzania	4567	11 202	134 002	2018
Zambia	3 126	9 403	31 051	2005
Zimbabwe	3 427	18 481	78 786	2002

The corridors identified for development are the:

- **Bas Congo Corridor** from the Port of Matadi to Kinshasa in the DRC
- **Beira Corridor** from Zambia and Malawi through Zimbabwe to the Port of Beira in Mozambique
- **Central Corridor** from Burundi, Rwanda, Uganda and the eastern part of the DRC through Tanzania to the Port of Dar es Salaam
- **Dar es Salaam Corridor** from Walvis Bay in Namibia through Zambia, the DRC and Malawi to the Port of Dar es Salaam in Tanzania
- **Limpopo Corridor** from Zimbabwe to Mozambique
- **Lobito Corridor** from the DRC through Zambia to the Port of Lobito in Angola
- **Malanje Corridor** from the Malanje Province to the Port of Luanda in Angola
- **Maputo Corridor** from the Gauteng Province in South Africa to the Port of Maputo in Mozambique
- **Maseru–Durban Corridor** from Maseru in Lesotho to the Port of Durban in South Africa
- **Mtwara Corridor** from Malawi to the Port of Mtwara in Tanzania
- **Nacala Corridor** from Zambia through Malawi to the Port of Nacala in Mozambique
- **Namibe Corridor** from Namibia to the Port of Namibe in Angola
- **North–South Corridor** through the DRC, Tanzania, Zambia, Zimbabwe and Botswana to Gauteng and the Port of Durban in South Africa
- **Trans–Caprivi Corridor** from southern DRC through Zambia to the Port of Walvis Bay
- **Trans–Cunene Corridor** from central and southern Angola to the Port of Walvis Bay
- **Trans–Kalahari Corrido** from the Gauteng Province in South Africa through Botswana to the Port of Walvis Bay
- **Trans–Orange Corridor** from the Northern Cape Province of South Africa to the ports of Walvis Bay and Lüderitz in Namibia.

Many corridors will be multi-modal, including road, rail and waterways. These corridors are aimed at connecting centres to each other and to ports and airports. However, the road and rail network along these corridors is currently not continuous, requiring more development over and above the upgrading of existing roads. The need to build multi-lane highways and rail lines at acceptable grades will require the construction of many bridges, but several countries complain of the lack of bridge-building expertise.

Furthermore, many coastal and waterway ports need to be upgraded and new ports need to be built. Modern cargo-handling equipment will also need to be designed and installed. Rail and port engineering expertise has declined over the years and needs to be redeveloped as part of construction programmes to ensure that there is sufficient capacity to operate and maintain the new or upgraded infrastructure.

Many airports also require expansion to handle both increased passengers and increased freight.

Transport refers not only to the networks and infrastructure, but also to the vehicles, whether cars, heavy earthmoving or freight vehicles, rolling stock, aircraft, boats, ships, tugs, etc. Considerable engineering expertise is required to manage such fleets, optimise their usage and handle maintenance programmes. Public transport is also important and several major cities are busy implementing Bus-Rapid-Transport (BRT) systems.

Several countries have large maintenance facilities for rolling stock and lament the shortage of engineering management skills to manage maintenance programmes. Aeronautical and marine engineering skills are also required, given the number of airlines in the region and the length of coastline. Furthermore, aviation and maritime navigation systems need to be upgraded.

COMMUNICATIONS

The status of the communications sector in the SADC region is summarised in Table 14, showing the percentage of each service available, relative to the population. Fixed-line communication is slowly decreasing in popularity as wireless systems offer more flexibility and functionality, and are more universally accessible.

Table 14: Percentage connected to services, 2016
(Eswatini 2012)

COUNTRY	FIXED LINE %	MOBILE %	INTERNET %
Angola	1	45	13
Botswana	6	137	63
DRC	0	44	6
Eswatini	3	74	29
Lesotho	1	103	27
Madagascar	1	32	5
Malawi	0	40	10
Mauritius	30	143	52
Mozambique	0	52	18
Namibia	8	107	31
Seychelles	20	175	87
South Africa	8	147	54
Tanzania	0	72	13
Zambia	1	72	26
Zimbabwe	2	80	23

The majority of international bandwidth is carried to and from Europe and Asia using fibre optic undersea cabling. Links which serve the SADC region, from the oldest to the most recent, are:

- **SAT-2 (South Atlantic Telecommunications)** which runs along the west coast of Africa from South Africa to Portugal and Spain, and was the first undersea fibre cable to the region, replacing the coaxial telephone cable laid in 1968
- **SAFE (South Africa Far East)** which links South Africa to Malaysia, with landing points in Mauritius, Reunion and India
- **SAT-3 (South Atlantic Telecommunications)** which runs along the west coast of Africa from South Africa to Portugal and Spain
- **SEACOM** which runs along the east coast of Africa and links South Africa to Egypt and India
- **LION (Lower Indian Ocean Network)** which connects Reunion, Mauritius and Madagascar
- **EASSy (Eastern Africa Submarine System)** which runs from South Africa to Sudan, with landing points in Mozambique, Madagascar, the Comoros and Tanzania, among others
- **WACS (West Africa Cable System)** from South Africa to the UK, which connects countries along the west coast of Africa, including Namibia, Angola and the DRC, to one another
- **ACE (African Coast to Europe)** which is an additional link connecting west coast countries to one another from South Africa to France
- **SEAS (Seychelles to East Africa System)** which connects the Seychelles to Africa through Tanzania
- **SACS (South Atlantic Cable System)** which connects Brazil to Angola. As it links the MONET fibre cable from Brazil to the USA, it gives Angola a more direct connection to the USA.

Further cables being installed or planned are:

- **METISS (MEltingpoT Indianoceanic Submarine System)** which will connect South Africa to Mauritius, Madagascar and Reunion
- **IOX (Indian Ocean Exchange)** which will connect South Africa to India through Mauritius
- **MARS** (**Mauritius and Rodrigues Submarine Cable System**) which will connect the islands of Mauritius
- **SABR (South Africa Brazil)** which will connect Brazil to South Africa
- **PEACE** (**Pakistan and East Africa Connecting Europe)** which will connect the Seychelles to Europe
- **Africa-1** which will connect South Africa to France and the Middle East
- **SAex-1 (South Atlantic Express)** which will connect South Africa to the USA through the South Atlantic islands
- **SAex-2 (South Asia Express)** which will connect South Africa to India and Singapore.

Connections to landlocked countries have been developed to allow them to access international connectivity.

Connectivity within the SADC community is generally accomplished using a fibre optic backbone, as it supports long distances and high bandwidth. It has been costly to implement in towns and cities due to the cost of laying cables. Overhead installations have also been used to reduce costs. Fibre optic networks allow for faster and more reliable access to services such as communication, wireless internet and fixed-line broadband services.

Fibre To The Premises (FTTP), which consists of two subsectors – Fibre To The Home (FTTH) and Fibre To The Business (FTTB) – is slowly becoming the new benchmark for connectivity, providing faster access, lower consumer and operating costs, as well as environmental benefits.

The implementation of FTTP requires bandwidth to be available in the national infrastructure and several countries have started or have already implemented FTTP services, including South Africa, the Seychelles, Zimbabwe, Mauritius and Tanzania.

One of the primary providers across the African continent is Liquid Telecom which has over 50 000 km of fibre optic networking and connects to five major submarine fibre cables linking Africa to Europe and Asia. This vast network requires constant expansion and overhauling to maintain uninterrupted connectivity.

Mobile connectivity is widely used as the primary means to access the internet as it is easily accessible throughout most of the SADC countries. The most widely used providers are MTN and Vodafone. However, wireless distribution stations depend on the national networks to be reliable and have sufficient bandwidth, but, in most cases, this is where the sector falls short.

An expanded team of electronic, telecommunications and systems engineers and technicians is needed to harness the opportunities that current connectivity offers, to expand connectivity and to maintain the infrastructure and networks.

Several communication projects are taking place in the SADC region, such as the Square Kilometre Array (SKA). It consists of a series of telescope dishes covering a square kilometre which will search for signatures of life in the galaxy. The project aims to revolutionise science and exploration in areas such as gravitational waves, pulsars, relativity and investigating black holes. It will provide a jump in capability, providing four times more resolution, five times more sensitivity and will be able to map the sky 60 times faster than the Karl G. Jansky Very Large Array (VLA), currently the best telescope at similar frequencies. It will also bring together people, processes and data, and will pioneer research in optical transport and big data. The countries involved include South Africa, Botswana, Madagascar, Mauritius, Mozambique, Namibia and Zambia.

CONSTRUCTION

The value and structure of the construction sector in the region can be seen in Table 15. The sector is very sensitive to the state of the economy and suffers boom and bust cycles largely linked to government spending. The sector is characterised by three types of organisation, namely consulting engineers, contractors and construction materials suppliers. The manufacturers of construction materials fall under *Manufacturing*.

As major projects can pose serious threats to public health and safety, in terms of both the design of the final product and the dangers associated with the construction phase, many countries have taken to setting up construction industry boards or councils which are usually statutory bodies set up to regulate the appointment of service providers. In some countries, this control is exercised within the Ministry of Public Works or Construction.

The approach taken is to determine the capacity and skills set of each organisation to determine what size and type of project it is capable of taking on. Normally, contractors are categorised into four to six levels, depending on the capital they have access to, the extent of their plant and equipment, and their professional skills. A minimum number of engineering and construction professionals are specified per category. As companies gain experience and grow, they may apply to be moved up into the next category to take on bigger and more complex projects. Of concern is the fact that some countries, although regulating, have not prescribed skills sets.

Other countries have not set any requirements but do require consultants and contractors to apply for licences. At the time of applying for the licence, they must prove that they have adequate public liability cover in case of accidents. In those countries where there are no national controls, it was not possible to determine the exact number of consulting engineering practices or contractors – the estimates provided reflect the numbers which belong to VAs and are therefore less than the total number.

The dominance of foreign contractors in many countries limits the opportunities to grow local capacity. Chinese construction companies are said to dominate the construction sector in many countries, with India, Portugal, Brazil, South Africa and others

Table 15: Construction metrics

(*Malawi GDP data 2012)

COUNTRY	Contribution to GDP 2015 (US$ million)	Construction % of GDP 2015	% contribution to engineering GDP	No. of consulting practices	Registration of consultants	No. of contractors	Registration of contractors**	COUNTRY OF ORIGIN OF MAIN FOREIGN CONTRACTORS
Angola	$14 729	13.0%	23.0%	~30	R	1 812	R	Brazil, China, Portugal, South Africa, Spain, UAE, UK, USA
Botswana	$940	7.2%	17.1%	45	L	>2 000	L	China, Egypt, Korea, South Africa
DRC	$1 614	4.7%	6.3%	>30	L	>286	L	Brazil, China, France, Netherlands, South Africa, Spain, USA
Eswatini	$106	2.9%	5.5%	26	C	440	C	South Africa, Taiwan
Lesotho	$127	6.3%	14.3%	50	-	1 400	-	China, South Africa
Madagascar	$258	3.2%	4.6%	>5	-	~2 000	-	China, France, UK
Malawi*	$184	3.4%	6.9%	50	C	850	C	China, Portugal, South Africa
Mauritius	$457	4.4%	12.4%	70	B	1 154	B	China, India
Mozambique	$349	2.5%	4.3%	~63	R	>5 000	R	Brazil, China, India, Italy, Portugal, South Africa
Namibia	$695	6.6%	15.5%	90	-	>450	-	China, Italy, South Africa
Seychelles	$43	3.7%	11.1%	20	-	80	L	China, India, Mauritius, UAE
South Africa	$11 398	4.0%	9.7%	600	-	122 890	B	Many international equipment suppliers and JVs
Tanzania	$6 157	14.6%	22.9%	205	B	9 300	B	China, Egypt, India, Japan, South Africa
Zambia	$2 163	10.7%	22.3%	76	C	5 650	C	China, Egypt, India, Italy, Korea, Lebanon, Portugal, South Africa
Zimbabwe	$429	3.4%	6.5%	60	-	>600	-	Brazil, China, India, Korea, Portugal, South Africa

**B=Registration Board C=Registration Council L=Licence from government R=Registration by government

also competing for work. The list shown in Table 15 is not comprehensive but gives a sense of the spread of countries competing for work.

Local contractors complain that they cannot compete against foreign contractors which are able to price below them, due to support from their governments. Other complaints include the use of foreign labour and materials on projects awarded to international companies, when local construction skills are unemployed and local manufacturers are looking for business. Controls on international contracts are needed to ensure the maximum use of local skills, material and equipment.

In South Africa, the labour laws and requirements for Broad-based Black Economic Empowerment generally preclude the direct appointment of international contractors. Where specialist skills are required, joint ventures are formed between local and international specialist companies.

Construction contracts are the perfect setting for training. Conditions should be set in all contracts for the training of local graduates and apprentices on public sector projects. Contracts should include guidelines and controls must be put in place to ensure that all trainees are given a suitable variety of tasks and are challenged and coached.

Throughout the country reports it will be evident that major projects have been identified, but few can proceed without funding. There is a limited number of bankable projects, i.e. those that are financially viable and that will not pose a risk to investors. Thorough research and assurance of return on investment are required before many projects can proceed. For this reason TBD ('to be determined') is shown under the cost and date columns associated with many projects in the country reports.

THE AFRICA INFRASTRUCTURE DEVELOPMENT INDEX (AIDI)

The Africa Infrastructure Development Index (AIDI), is a good indicator of the extent and quality of infrastructure in Africa. It is a measure out of 100. The Seychelles is ranked the highest, with an index of 94.324, followed by Egypt at 85.847.

INDICATORS

The AIDI is based on four major components, namely transport, electricity, ICT and water and sanitation. These components are disaggregated into nine indicators that have a direct or indirect impact on productivity and economic growth. They are summarised as follows:

I. Transport

- **I.a Total Paved Roads (km per 10 000 inhabitants):** The country's total road length surfaced with crushed stone (macadam), hydrocarbon binder or bituminised agents, concrete, or with cobblestones. The indicator is measured in km per 10 000 inhabitants to give an indication of access to paved road network.
- **I.b Total Road Network in km (per km^2 of exploitable land area):** The total road length (both paved and unpaved roads) relative to the exploitable area of the country, where exploitable area is the total area minus the surface area of deserts, forests, mountains and other inaccessible areas.

II. Electricity

- **Net Generation (million kWh per hour per inhabitant):** The total electricity production of a given country, including the energy imported from abroad. This includes both private and public energy generated.

III. ICT Composite

- **III.a Total Phone Subscriptions (per 100 inhabitants):** This refers to both fixed-line and mobile.
- **III.b Number of Internet Users (per 100 inhabitants):** The estimated number of internet users using any device (including mobile).
- **III.c Fixed (wired) Broadband Internet Subscribers (per 100 inhabitants):** Total internet subscriptions using fixed-line (wired) broadband technologies, excluding access through mobile cellular networks.
- **III.d International Internet Bandwidth (Mbps):** The sum of capacity of all internet exchanges offering international bandwidth (if incoming exceeds outgoing, incoming capacity is used).

IV. Water and sanitation composite

- **IV.a Improved Water Source (% of population):** Access to an improved water source able to supply at least 20 litres per person per day from a source within 1 km of the dwelling.
- **IV.b Improved Sanitation Facilities (% of population):** This refers to access to facilities in which the disposal of excreta can prevent human, animal and insect contact with excreta.

RANKING

Many countries in the region rate very poorly on the Index, with Mozambique at 44, Madagascar at 46 and the DRC at 50 out of 54. Somalia held 54th position with an index of just 3.36 out of 100. Table 16 shows the overall index for 2018. The low ranking in many countries indicates the extent of upgrading and development of both economic infrastructure and water and sanitation services required. This, however, cannot take place without investment.

It is interesting to note that the Index has more than doubled in Angola, Madagascar and Tanzania over the 15-year reporting period. In each case this can be attributed largely to investment in major mining projects and the development of associated infrastructure.

Table 16: AIDI values per country, 2018
(Source: African Development Bank)

COUNTRY	RANKING 2018	AIDI 2003	AIDI 2018	% INCREASE	WSS	ICT	ELECTRICITY	TRANSPORT
Angola	29	7.3	19.04	161%	40.14	11.78	6.4	1.87
Botswana	10	24.73	36.79	49%	80.82	30.63	21.51	22.28
DRC	50	4.02	8.15	103%	31.93	6.99	1.85	1.64
Eswatini	17	13.22	25.76	95%	61.6	18.32	5.78	8.36
Lesotho	35	12.83	16.01	25%	54.56	16.35	4.11	7.41
Madagascar	46	3.14	10.73	242%	23.42	6.45	0.95	3.01
Malawi	25	11.51	21.02	83%	65.84	7.02	2	4.83
Mauritius	5	42.1	76.79	82%	97.51	58.67	39.86	38.39
Mozambique	44	5.88	12.49	112%	27.11	11.18	12.04	2.02
Namibia	13	24.72	28.65	16%	63.34	22.09	10.54	15.49
Seychelles	1	47.43	94.32	99%	96.87	59.78	63.81	50.32
South Africa	4	46.07	78.53	70%	79.99	76.94	74.86	21.91
Tanzania	43	5.17	12.54	143%	28.16	10.43	1.82	3.27
Zambia	23	14.42	22.29	55%	48.74	14.93	14.08	4.71
Zimbabwe	19	22.48	24.52	9%	53.97	16.36	10.38	11.69

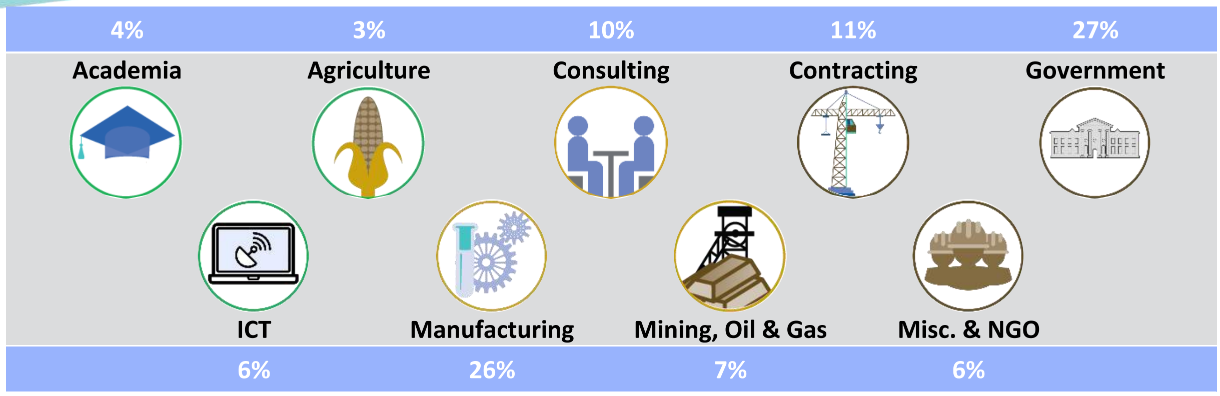


Figure 19: Percentage of engineering practitioners employed per sector

NUMBERS PER SECTOR

The distribution of disciplines employed in each country was shown in Chapter 2. Figure 19 shows the percentage split of practitioners in each sector and Table 17 shows the estimated numbers per sector.

Construction has been split into consulting and contracting, as they have significantly different employment profiles. Since the bulk of employment relating to energy, water, transport and communication is in government, the two sectors have been combined under government, which, in this case, represents all spheres of government.

With the spread of information technology, automation and telecommunications, major private sector activities have emerged, hence a separate measure of ICT in the private sector. Typically, this would include staff in mobile service provider, systems, software and communication companies.

Mining requires specialist skills, including mining and metallurgical, mechanical and electrical engineers. More recently, specialists in oil and gas have become necessary, not only in Angola, but in several countries that have discovered coastal reserves.

Engineering skills are also to be found in many industries that are not directly related to engineering, but are affected by or influence engineering decisions, hence a category for Miscellaneous. Many practitioners are also involved in the NGO sector, working on community projects to address the delivery of basic services, enhance agricultural production, training, etc.

It must be emphasised that these numbers represent an estimate only, based on limited responses and data availability throughout the region, as discussed under *Estimated Numbers* in Chapter 2.

Table 17: Estimated number of engineering practitioners employed per sector
(Engineers only)*

COUNTRY	Academia and research	Agriculture	Consulting	Contracting	Government	ICT, systems and telecoms	Manufacturing and suppliers	Mining, oil, gas and quarrying	Miscellaneous and NGOs	Total	% in government
Angola*	500	300	300	1 000	3 250	300	1 700	1 200	450	9 000	36.1%
Botswana	300	50	500	550	2 500	400	500	750	450	6 000	41.7%
DRC	800	2 000	400	1 000	5 000	1 000	5 000	1 000	1 800	18 000	27.8%
Eswatini	50	50	200	280	650	50	150	10	160	1 600	40.6%
Lesotho	50	20	150	160	350	80	150	80	110	1 150	30.4%
Madagascar	700	1 000	400	1 000	1 850	700	3 500	750	1 100	11 000	16.8%
Malawi	140	250	300	700	1 200	100	300	50	160	3 200	37.5%
Mauritius	350	50	400	1 400	1 400	500	600	50	250	5 000	28.0%
Mozambique*	500	550	700	1 300	3 500	600	2 500	800	550	11 000	31.8%
Namibia	150	50	500	400	650	60	450	400	140	2 800	23.2%
Seychelles	20	20	50	90	170	30	90	10	30	510	33.3%
South Africa	2 000	500	14 000	9 000	28 000	9 000	34 000	8 000	5 500	110 000	25.5%
Tanzania	1 800	700	4 000	6 000	8 000	1 000	6 000	1 000	1 500	30 000	26.7%
Zambia	400	300	700	1 100	3 000	500	3 800	1 600	600	12 000	25.0%
Zimbabwe	400	100	400	700	2 000	400	2 000	1 200	400	7 600	26.3%
TOTAL	**8 170**	**5 940**	**23 000**	**24 680**	**61 520**	**14 720**	**60 740**	**16 900**	**13 200**	**228 860**	**26.9%**

Part 2
Findings and Recommendations

PART CONTENTS

Many trends have emerged which are impacting on the development of engineering skills in the region. Countries have many ambitious plans, which will require large numbers of experienced engineering professionals. However, the funds are simply not available for many projects to be considered. Furthermore, few countries have sufficient expertise for the current workload, and public sector structures struggle to maintain existing services, let alone expand services and deliver new solutions. Many of the bottlenecks will require policy decisions, funding or both to be addressed.

The bottlenecks and recommendations are considered under the headings relating to development, employment and appointment of professionals, and investment in infrastructure, as follows:

Chapter 7

Theory

The theoretical training of engineering professionals is not limited to tertiary education, but starts from childhood, with adequate exposure to the concepts, thinking and theory that build engineering problem-solving capabilities. From early childhood all the way up to post-doctoral studies, the phases to develop engineering experts are theoretical training phases. It was not within the ambit of this study to cover the full education life cycle, but the importance of each phase must be considered when developing national policies.

The critical elements on which the engineering profession must comment, and in which it must play a role, are schooling and tertiary education.

SCHOOLING

There are several areas of concern in the schooling system with regard to the development of engineering practitioners. Access to education is still a major barrier, as can be seen in Figure 20. This means that many with aptitude will never have the opportunity to enter the engineering space. Coupled with this, the teaching capacity and inadequacy of infrastructure and resources present further challenges which impact on developing the potential of those in the system.

INADEQUACY IN SCHOOL MATHEMATICS AND SCIENCE

The quality of teaching and access to high school education presents a problem in the region. The numbers achieving the required pass marks are inadequate to meet the need of the technical, scientific, actuarial and other professions requiring high-performance school leavers who have excelled in mathematics.

In the attempt to extend education to the entire population, the complexity of mathematics and other subjects has been reduced to accommodate large classes and make teaching easier for underqualified teachers. Furthermore, the move to the outcomes-based approaches to education in several countries has, due to the size of classes, meant that process, rather than principles, have been taught. This has had a detrimental effect on engineering education.

As far back as 1998, Prof. Les Clarke, Dean of Civil Engineering at Birmingham University, complained that due to the change in the school teaching approach, it had become necessary to teach mathematics and physical concepts at university level. This required more teaching time which was problematic considering the already demanding content of engineering degrees.

Angola's rationale for opening many more universities is to '*better skill and create employment opportunities*', which is the view adopted by many countries. However, engineering students with an inadequate foundation in mathematics and science have little hope of succeeding. Emphasis should rather be placed on improving teaching at school level.

In many countries, the Y model of choosing a technical or academic stream after Grade 9 offers the opportunity for technical mathematics to be taught for the last three years of secondary education, and emphasis should be placed on developing those with an aptitude for engineering at this stage, rather than expecting universities to teach principles which should have been learnt at school.

Bridging or foundation courses have been introduced to assist those entering higher education to 'catch up' on poor school teaching. However, if there has been no grasp of the basic principles early on,

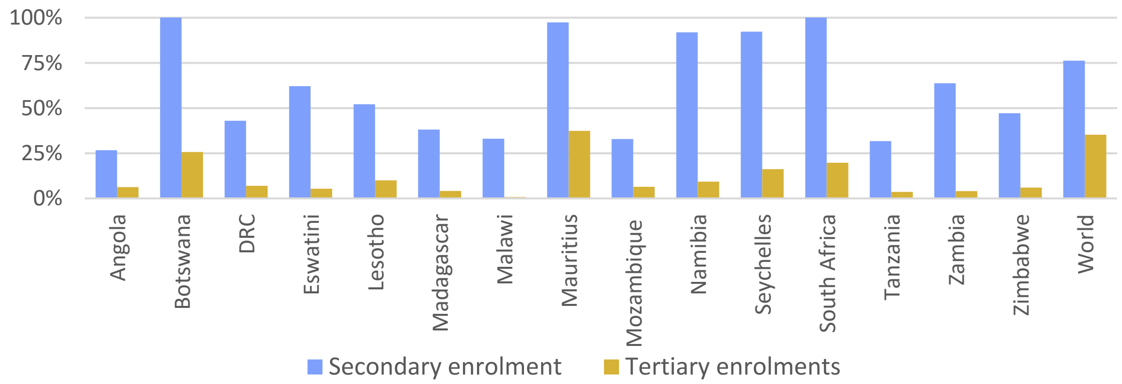


Figure 20: Percentage enrolments in secondary and tertiary education
(UNESCO from 2012 to 2016)

understanding subsequent concepts is difficult. As a result, those arriving at university with poor school results require years to catch up, rather than being able to do so in the short period offered as part of bridging.

Detailed analyses of the challenges have been carried out in many countries. The temptation is always to provide more books and teachers, but without adequately qualified teachers, the concepts and principles so vital for engineering students cannot be developed. Teacher development is therefore one of the important elements for developing engineering skills for the future.

The Centre for Development and Enterprise (CDE) in South Africa has carried out ongoing research in this field for many years. In an early publication, *From Laggard to World Class*, they suggested that scholarships for learners with an aptitude for mathematics should be considered to stream them into stronger schools to develop their potential from an early stage. In a later publication, they cautioned that addressing the emotional and social difficulties faced by such learners was essential as the transition from a weak school to a high-performance and highly competitive environment can be very challenging.

Although the CDE approach will make a difference to individual performance, the sheer numbers requiring access and better resourced schools will require years of intervention. In the absence of adequately trained teachers, technology should be harnessed. YouTube has proved to be a useful tool for teaching. Organisations such as the Kahn Academy, and many others, have created online learning material for all grades. Group work should be encouraged, to allow those who have grasped concepts to assist those who are struggling.

A young South African wishing to study biotechnology proved this approach to the research team. Although earning a First Class pass in science in Grade 12, his mark of 53% for mathematics precluded him from entry into studying biotechnology. On investigation is was found that his school mathematics teacher had only passed Grade 10, and the class did not cover the full syllabus. The young man was given access to a laptop, Wi-Fi and YouTube and after three weeks of self-study, rewrote his mathematics exam and earned 69%. This allowed him to enter biotechnology studies. He is thriving at university, getting good results in all his subjects.

A massive campaign to roll out online learning, to supplement the inadequacy of teaching capacity and material, needs to be mounted. This would require setting up hotspots and acquiring appropriate technology such as tablets or screens per classroom to access available material among others. Changes in teaching approaches need to be considered to allow teachers to be facilitators of online learning. Mobile technology and mobile applications have proved themselves throughout Africa. It is said that there are more mobile phones in Africa than taps. Many school goers in the most remote areas are connected to the extensive mobile networks.

The One Laptop Per Child (OLPC) programme in Rwanda has improved class attendance, learner engagement and family involvement in education and should be replicated in all countries. Donor Agency and corporate commitment to sponsor technology and the support of mobile operators to include remote schools in their development planning is required.

CAREER GUIDANCE

Several countries have suggested the need for more career guidance to attract high-calibre candidates into the field. A range of methods need to be considered, including presentations at schools, taking stands at career shows, including engineering and built environment examples in mathematics and science textbooks, creating career portals and providing detailed online material.

Young professionals should be encouraged to act as the role models by delivering presentations and making themselves available to counsel potential entrants into the field. VAs should be working with education ministries to identify schools with high-potential learners at which to carry out engineering career guidance.

ENCOURAGING FEMALE SCHOLARS

Large numbers are entering engineering studies, but the number of women is still very low in many places. *WomEng* has developed a suite of support programmes for women in engineering, including high school STEM awareness. Funding should be raised to expand the *WomEng* programmes throughout the region.

TERTIARY EDUCATION

There are many challenges in tertiary education, including

- High enrolments
- Inconsistencies in qualifications
- Poor throughput
- Excessive numbers graduating
- A proliferation of higher education institutions of varying calibre

- Inconsistent accreditation regimes.

HIGH ENROLMENTS NOT JUSTIFIED

Although Figure 4 shows correlation between the GDP per capita and the number of engineering practitioners employed in a country, it is important to understand that engineers on their own do not raise the GDP per capita, but it is rather engineering development that is the key driver of growth. There has been the mistaken belief that by increasing the number of engineering graduates, growth will take place of its own accord.

For engineering development to take place, investment is required, along with experienced engineering personnel to investigate, plan and manage developments. The demand to increase dramatically the number of students enrolling in engineering classes cannot be justified until long-term investment is committed and projects are being rolled out. Development will offer internship and training opportunities for graduates, without which the prospects of employment will be limited. Growing the engineering team should be a slow, deliberate process linked to development and increasing demand.

It would seem that a directive has been issued throughout the region to increase the number admitted for engineering studies without the matching demand. The stretch targets have resulted in large classes and high student-to-academic ratios. This affects both the throughput and quality of graduates. Best practice should be considered, and numbers limited to ensure a higher throughput and calibre of graduates.

INCONSISTENCIES IN QUALIFICATIONS

The tertiary approach to educating engineers, technicians and technologists varies considerably across the region. In most countries, only one or two universities were in place in the 1960s and 1970s, modelled on universities in the colonial power at that time. Usually at least one offered an engineering degree. Students would apply for entry and would either receive a bursary or be funded by their family. As there were limited places and graduate numbers were small, students would generally have no difficulty in finding employment on graduation.

In parallel, technical colleges offered the theoretical and practical training associated with the development of a trade- or craftsperson. This was demand-led training, whereby a young employee on the shop floor with aptitude was sent to night school or on block releases to learn more advanced theory and processes, associated with the work being carried out at the time. With the advent of polytechnics, the theory was offered on a semester basis, and students could apply to enter such courses without being employed. The extent and duration of theory taught was extended. A national diploma or equivalent was awarded which normally included two years of theory and a third year spent in industry gaining practical experience. In many instances, as the student was not a permanent employee, investment into the extent and quality of practical training was limited. Furthermore, one year in practice was substantially less practical experience than had previously been gained in the workplace when the student was employed and studying part-time. Industry complains that technicians have had inadequate practical training, but without their commitment to invest in the process or without a change in the structure of technician training, this situation will persist.

With the more recent emergence of universities of technology, technician training has been enhanced to that of technologist or engineer, reducing the number of technicians being trained in several countries. In other countries, the colleges have expanded the levels that they cover, offering Level 5, 6 and, in some instances, level 7 qualifications.

Table 18 compares the types of training approaches and Figure 21 shows the range of models found in the region. The detailed differences are outlined under each category heading below.

Engineers

The approach to educating engineers is reasonably similar throughout all countries. Four- or five-year professional degrees are offered at traditional universities, or the more recently formed private universities. The initial years include mathematical and scientific subjects to develop a sound theoretical base and problem-solving capabilities, after which applied subjects in a range of subdisciplines are taught.

Most degrees tend to span all the subdisciplines within a discipline, rather than focus on narrow subdisciplines. Exceptions have been the emergence of irrigation engineering degrees, rather than agricultural engineering degrees including irrigation, and renewable energy degrees, rather than electrical engineering degrees including consideration of renewable energy. While the specialisation may be good for the specific topic, the question needs to be asked whether these specialisations should not be taught at post-graduate level after completion of a generic engineering degree in the discipline.

Table 18: Comparison between types of training approach

<table>
<tr><th>COUNTRY</th><th>TECHNICIAN</th><th>TECHNOLOGIST</th><th>ENGINEER</th></tr>
<tr><td>Angola</td><td>Technical Schools
Diploma
From craft training after Grade 9
Complete two years after craft qualification</td><td>Universities
Bacharelato
Known as Technical Engineers</td><td>Universities
Licenciatura
Five years
Third year in industry</td></tr>
<tr><td>Botswana</td><td>Colleges and Universities
Diploma and Advanced Diploma
Varies</td><td>Colleges
BSc
Three years</td><td>Universities
BEng or BSc(Eng)
Four years
Vacations in industry</td></tr>
<tr><td>DRC</td><td>Institutes
Gradué en Techniques Appliquées
Three years (excl. foundation)</td><td>Institutes
Licencié en Techniques Appliqués
Two years after Gradué</td><td>Universities
Ingénieur Civil
Five years (excl. foundation)</td></tr>
<tr><td>Eswatini</td><td>College
Diploma
Three years
Six months in industry</td><td>N/A</td><td>Universities
BEng
Four years – Biosystems
Five years – Electrical</td></tr>
<tr><td>Lesotho</td><td>College
Diploma</td><td>N/A</td><td>University
BEng
Four-and-a-half years
Six months in industry</td></tr>
<tr><td>Madagascar</td><td>Universities
Licentiate
Three years</td><td>N/A</td><td>Universities
Master’s
Five years
Fourth year in industry</td></tr>
<tr><td>Malawi</td><td>Polytechnic
Diploma</td><td>N/A</td><td>Universities
BEng
Five years
Six months in industry</td></tr>
<tr><td>Mauritius</td><td>Institutes, Colleges and Universities
Diploma, HND or
C&G Advanced Diploma
(Entry O levels)</td><td>Universities
BSc
Three years
(Entry A levels)</td><td>Universities
BEng(Hons)
Three years
(Entry A levels)</td></tr>
<tr><td>Mozambique</td><td>Technical Schools
Diploma
From craft training after Grade 9</td><td>N/A</td><td>Universities
Licenciatura
Four or five years</td></tr>
<tr><td>Namibia</td><td>Universities of Technology
National Diploma (ND)
Three years
One year in industry</td><td>Universities of Technology
BTech
One year full-time or two years part-time after ND</td><td>Universities
BEng or BSc(Eng)
Four years
Vacations in industry</td></tr>
<tr><td>Seychelles</td><td>College
C&G Advanced Diploma
Part-time</td><td>N/A</td><td>N/A</td></tr>
<tr><td>South Africa</td><td>Universities of Technology
National Diploma (ND)
Three years
One year in industry</td><td>Universities of Technology
BTech
One year full-time or two years part-time after ND</td><td>Universities
BEng or BSc(Eng)
Four years
Vacations in industry</td></tr>
<tr><td>Tanzania</td><td>Universities, Institutes and Colleges
Diploma</td><td>Universities, Institutes and Colleges
BEng</td><td>Universities
BSc(Eng)
Three to four-and-a-half years
Six to 18 months in industry</td></tr>
<tr><td>Zambia</td><td>TVETA Colleges
Advanced Certificate</td><td>Universities or Colleges
Diploma</td><td>Universities
BEng
Four years, 3rd and 4th year vacations in industry</td></tr>
<tr><td>Zimbabwe</td><td>Institutes and Polytechnics
National Diploma (ND)
Three years
One year in industry</td><td>Institutes and Polytechnics
Higher National Diploma (HND)
One year full-time or two years part-time after ND</td><td>Universities
BTech(Hons), BEng, BSc(Hons)
Five years
One year in industry</td></tr>
</table>

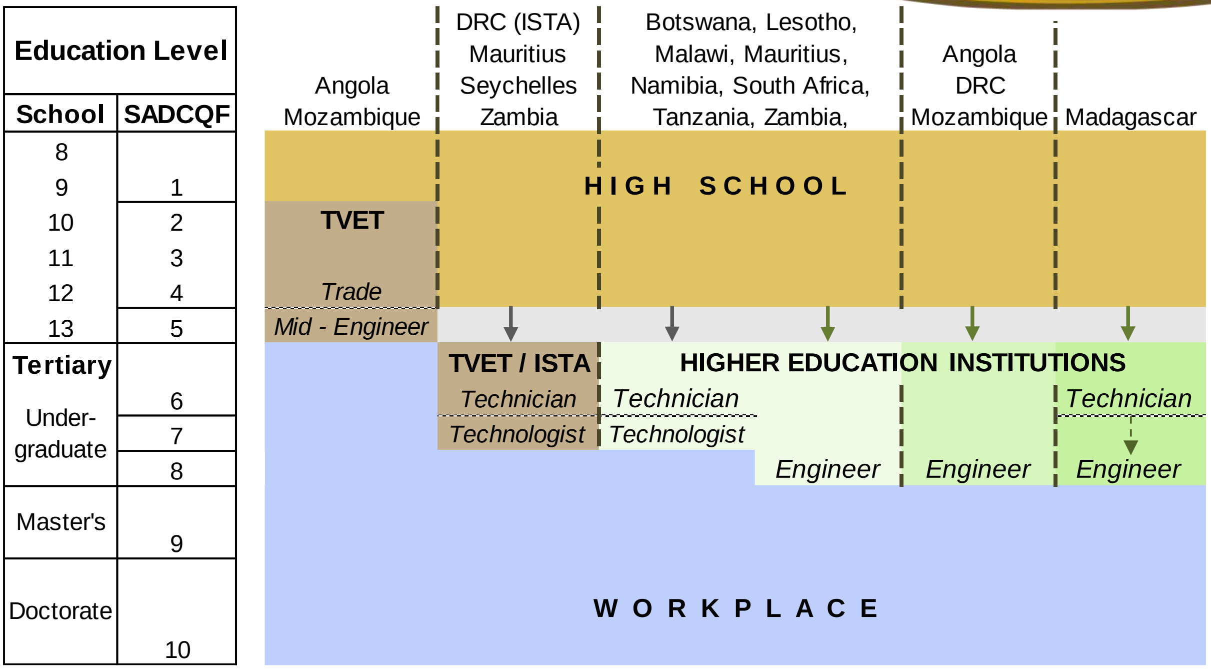


Figure 21: The structure of education models in the SADC region

The English-speaking countries have largely modelled their qualifications on British degrees. It is necessary to complete all years of study before graduating as an engineer. There are no exit points in earlier years. The engineer qualification is known as a Bachelor's degree, with the nomenclature varying from BEng, BSc(Eng), BEng(Hons) or BSc(Eng)(Hons) or BTech(Hons), depending on the country, institution and duration of study.

Most degrees require that some time is spent in industry, but usually no more than six months, and in several countries only the summer vacations each year.

The engineer qualification in French- and Portuguese-speaking countries is also a four- or five-year professional degree, but it is possible for students to exit after two or three years and work as technicians or graduates – the terminology varies from country to country. In Madagascar students completing the full qualification offered by all types of institutions are recognised as engineers, while in the DRC only those completing qualifications offered by universities are considered to be engineers.

Historically, the training of engineers in universities versus polytechnics was different in these countries, resulting in university-trained graduates being called engineers and polytechnic-trained graduates being known as technical engineers. In Angola public and private universities offer different structures and content in their degrees, which makes accreditation difficult, but graduates from both are now recognised as engineers. The need for alignment is acknowledged.

In the DRC qualifications span six years, the first year being a foundation year. The structure of each qualification is presented in the DRC country report.

The introduction of LMD

With the advent of the Bologna Accord between European countries to ensure comparability in the standards and quality of higher education qualifications, the structure of qualifications has been changed into three cycles – the Bachelor's degree of 180 to 240 credits, known as the Licentiate, the Master's degree of 90 to 120 credits, and the Doctoral degree – hence the acronym LMD.

The shortening of the first cycle has raised concern about the reduced time to present the required content for training of engineers and several French- and Portuguese-speaking SADC institutions have expressed the need rather to align with the higher education models adopted by the other countries in the region.

The World Bank has, however, funded several universities to develop the new curricula for the LMD system, hence there is now a mix of the old and new systems in these countries.

To be recognised as an engineer, students must complete a Master's degree. Students may leave after completing the Licentiate and return to complete their Master's at any stage. Of concern is the fact that students often do not return.

Technicians and technologists

The approach to the training of technicians and technologists varies enormously throughout the region.

In Botswana, Namibia, South Africa and some institutions in Zambia and Zimbabwe, technician training is offered at polytechnics or universities of technology. The training covers the full range of subdisciplines in any given discipline and is a mix of mathematical and applied subjects. The theory is less complex than that of the engineer qualification and is offered over two- or two-and-a-half years. The balance of the qualification is devoted to industrial attachment. These are stand-alone qualifications, which do not require an applied qualification to be completed first, such as with a trade.

In other countries and some instances in Zambia and Zimbabwe, technician and technologist training is offered by vocational colleges which are part of the Technical Vocational Education and Training (TVET) system in those countries. The qualifications may be locally developed, or the City and Guilds qualifications may be used. Qualifications may be stand-alone or may be a top-up to trade theory. In the case of the latter, the qualification will be narrowly focused, for example in automotive engineering rather than mechanical engineering in general.

In terms of City and Guilds qualifications, some countries consider Level 3 as technician and Level 5 as technologist training, while other countries do not recognise Level 3 for technicians but use Level 5 for technician training. The City and Guilds Level 6 qualification is not available in Africa, so theoretically their qualifications cannot be used for training technologists in the SADC region.

Not all countries recognise or offer training for technologists.

The need to review the approach to technician training

The change from the demand to the supply approach to technician training has made the qualification available for entry by school leavers. As a result, students are no longer linked to industry and do not get sufficient relevant practical experience during industrial attachments. As students are temporary staff, few companies have developed structured training for them to ensure that they become hands-on practitioners. The duration of industrial attachments is now far shorter than the period that technicians of the 1960s and 1970s spent in the workplace before graduating. Industry currently complains that graduates are not career ready and cannot be utilised once they have graduated without considerable training and associated investment on their part.

There is a need to revisit the structure and content of technician training to make it more relevant to industry and to return to demand-side training. In terms of the many different qualification structures at technician level in the region, and the definition of competence expected for qualifications recognised by the Dublin Accord, technician training may need to become more applied rather than being general theoretical training.

A possible SADC approach

The different structures and names of qualifications will make alignment difficult. However, recognising the philosophy of the qualification frameworks, a set of exit-level outcomes or graduate attributes needs to be developed per level for assessment of the knowledge gained, the complexity of problem-solving and the degree of autonomy and responsibility developed.

POOR THROUGHPUT

The quality of graduates is poor and the dropout rate is high at many tertiary institutions due to inadequate staffing and poor facilities and support. The bottlenecks that require attention include the following:

Infrastructure

- Facilities, laboratories and teaching space are limited and have not been expanded to cope with the increased enrolments in recent years. Most lecture venues were built for smaller classes and enlarging them is not always an option, as venues become audio-visually compromised.
- Many universities reported having antiquated equipment, some dating back to the 1970s, as well as not having enough sets of equipment for the large numbers enrolled.
- In many instances there is also a shortage of computers and up-to-date software.
- Library facilities cannot cater for the number of students enrolled and have not been modernised to include access to online research materials and books.

Staffing

The staff:student ratios present a challenge in many institutions. Ivy League and top universities in the UK tend to have ratios of 1:10 or less. In 2016 the average ratio for all universities in the USA was 15.2 and 16.9 in the UK. The ratio in South Africa was 1:30.3, which was lower than in most SADC countries.

In South Africa the ratio applies to institutions as a whole, but the number of students per lecturer generally increases in engineering courses due to the difficulty in attracting lecturers from higher paid opportunities outside of academia. Reports of ratios of 1:75 and higher were not uncommon in many countries.

The SADC region is not alone in its struggle with lecturer numbers. In Kenya, the pressure to admit more students in the 'double intake programme' exceeds the capacity of public universities. The number of lecturers being newly hired does not match the number of students being enrolled. The quality of education is now said to '*raise serious concern*'.

Returning to the findings from the region, the following should be noted:

- Academic staffing is the core of what it takes to make a meaningful impact to ensure the success of students. Staffing shortages, high vacancy rates, unsatisfactory staff:student ratios and staff attrition are evident across the system and severely compromise the ability to supply the necessary support to individual students.
- Institutions repeatedly advertise the vacancies and get few, if any, applications. The main reason for lecturing staff leaving or not wanting to enter the sector is the heavy load due to the large number of students and the lack of competitive packages.
- The existing lecture venues are not designed to accommodate large classes. They are at times split into two groups which doubles the teaching load.
- In some countries lecturing staff are expected to undertake research and supervise post-graduate students without a decrease in their lecturing load.
- University policies in some cases preclude the use of external specialists or retired professionals to supplement the teaching staff and act as mentors.
- The qualification levels of lecturing staff are not always appropriate for the qualifications being offered and there is insufficient funding to support them to continue with post-graduate studies.
- To fill posts, recent graduates are employed, many of whom see these jobs as a temporary measure until they find something more suitable. Without post-graduate knowledge, work experience or lecturer training, they can contribute very little to the development of their students.
- Few academics have had practical experience and cannot adequately contextualise the theory.
- Traditionally, lecturers were selected based on expertise in their field, and there was no requirement for them to have formal teaching qualifications. With the increasing load, the changing student profile and generational learning differences, they are not equipped to engage today's students in new and contemporary ways.
- There are not enough dedicated laboratory technicians to ensure that equipment is adequately set up, calibrated, operated and maintained, and to assist with practical sessions to achieve optimum results.
- Many universities do not have enough administrative staff to remove the burden of routine paperwork and reporting from overstretched academics.
- Professional registration and keeping up with the latest technology are important, but few institutions cover annual professional registration fees or membership of voluntary associations.

Curricula

Re-curriculation and modernisation of many courses and associated material should be considered. At many institutions, course content is still Eurocentric and does not consider rural or local challenges and solutions. According to a Zambian report, design and analysis training is weak and little time is spent on solving problems and developing new and creative ways for value addition.

Content should be presented to, and debated with, industry, governments and educational specialists to ensure that it is fit for purpose, and sufficiently challenges students to meet the requirements of the Accords. To ensure that graduates can cope with the ever-changing environment, skills in critical thinking, problem-solving, creativity, teamwork and managing people should be developed.

Teaching and learning

Teaching methods have not been adapted for the 21st century student and should include problem-based learning, blended learning and the use of clickers and the like to ensure engagement. The use of the 'flipped classroom' is proving successful where it has been introduced. Where students watch lectures online and attend classes to discuss topics and undertake associated activities, scores are seen to be higher than those of students who attend traditional courses. In their thought-provoking report entitled *Academically adrift: Limited learning on college campuses* relating to student success in the USA, the authors report that after two years at college, 45% of students show no progress with critical thinking, complex reasoning and writing – skills that are so critical for engineering students to develop. They attribute much of this to colleges not adapting to today's life and learning styles.

The learning environment is also important. Millennial learners tend to absorb more information and develop problem-solving techniques through dialogue. Open spaces for engagement and group work is important but is not always available.

Figure 22: Group work at ISUTC in Mozambique

Student support

In the early years of study where classes are very large, lecturers cannot identify and support all the students who are struggling for various reasons. These include:

- A poor foundation in mathematics and science
- Writing difficulties due to a large proportion of students' studying in their second language
- Lack of career and course guidance at school, resulting in students not being suited to the qualification chosen
- Challenges with living conditions due to inadequate funding
- Adjustment to university life, particularly for those transitioning from rural areas
- Lack of family and community support.

Funding

Making funding available for tertiary education is an ongoing challenge and there are never enough funds to cover all the shortcomings. Governments need to prioritise investment in engineering departments, and industry needs to be encouraged to subvent salaries or contribute to investment funds. Where industries require specialist knowledge and research to be carried out, they should be encouraged to fund professorial chairs and research students.

Although industry and funders are often happy to make funds available, funds are frequently diverted into other budgets. It is important that mechanisms are put in place to ensure that funding given to universities for specific initiatives are ring-fenced so that they are used for the chosen purpose.

Practical training

Industrial attachments allow students to understand the context in which they are learning. However, finding willing employers and monitoring progress is expensive and funding is no longer adequate to cover these activities. Without completing time in the workplace, students cannot graduate. In South Africa, to overcome this problem, the three-year national diploma has been repackaged into a two-year advanced certificate, which simply covers the theory. Once graduates enter the workplace, they need to work for a minimum of four years before they can apply for professional registration, as opposed to three years, which was the minimum requirement with a national diploma.

GOOD PRACTICE

The weaknesses in teaching, practical experience and resourcing have been recognised and there are interventions aimed at supporting tertiary education in various ways.

HEPSSA support

The Royal Academy of Engineering has recognised the need for academic support. Accessing funding from the Anglo American Group Foundation and the UK Government through the Global Challenges Research Fund, it launched the Higher Education Partnerships in sub-Saharan Africa Programme (HEPSSA) in 2016. This initiative focuses on strengthening relationships between academia and industry to produce academics and engineers with the skills and knowledge required to tackle local challenges.

To maximise impact, the programme is implemented through a 'hub and spoke' model. The hub universities are funded to undertake secondments with local industry partners, and in turn, share their experiences with a larger number of spoke universities through knowledge-sharing activities.

Additional sponsorship should be raised to expand this type of support to many more institutions.

The SAICE Code of Best Practice

In 2017, the South African Institution of Civil Engineering (SAICE) carried out a detailed study to develop a best practice guideline for civil engineering departments. The study sought industry's views on the acceptability of graduates, identified gaps in curricula, laboratory and practical training, and interrogated academia on the challenges they faced. Predictably, the range of challenges outlined above emerged. Researchers quantified the optimum structures, including academic staff and administrators; facilities, equipment, systems and other support required; as well as the teaching approaches that should be considered.

State-of-the-art equipment was identified for each type of laboratory and SAICE is currently drawing up a tool for civil engineering departments to use to determine appropriate staffing levels and equipment for their class sizes and subject mixes. The plan is to update the information each year. The intention of the best practice guideline and the schedules that will be generated from the tool is to assist faculties to motivate for additional funding and to give less-experienced academics a guide on which to build their departments. Using the guide will be important to ensure that institutions are not stretched beyond acceptable levels. The model should be expanded to all disciplines and developed for the region.

TOO MANY GRADUATES

The number graduating has increased substantially since 2005 as shown in Figure 23. Furthermore, the graphs do not represent the total number graduating in countries marked 'partial', as only partial datasets were received. This suggests that graduations could be higher.

The number graduating exceeds the number that can be absorbed, giving rise to the phenomenon of the unemployed graduate. The continued supply-side approach to education and training needs to change and become more reflective of demand. As outlined in Chapter 4, an increase of 5% to 8% of the workforce is required to accommodate growth and replacement demand per year. In some countries, graduations have exceeded 20%, and even higher percentages when stratified to levels of qualifications, as shown in Table 19. Graduates in these situations have limited prospects of employment.

Rationalisation of the numbers being admitted is critical in terms of throughput and graduate training. When selecting where to cut, countries need to consider their development priorities and retain those disciplines and qualifications that will address their needs. These are outlined in country reports.

Table 19: The number and percentage of graduates in 2015 compared to engineering practitioners in 2018

COUNTRY	IN THE WORKFORCE		GRADUATES				%	
	Engineer	Technician/ Technologist	Engineer	% Female	Technician/ Technologist	% Female	Engineer	Technician/ Technologist
Angola	9 000		1 200	25.6%			13%	
Botswana	3 319	2 681	117		345		4%	13%
DRC *[1]	6 700	11 300	1 176		2 500		18%	22%
Eswatini *[2]	550	1 050	139	21.1%	127	14.0%	25%	12%
Lesotho *[2]	450	700	20	24.1%	347	24.6%	4%	50%
Madagascar	4 000	7 000	896	22.8%	757		22%	11%
Malawi	1 750	1 450	202	17.8%		16.2%	12%	0%
Mauritius	2 000	3 000	501	20.4%	304		25%	10%
Mozambique	11 000		767	25.3%		31.0%	7%	
Namibia *[3]	1 550	1 250	99	0.0%	129	44.4%	6%	10%
Seychelles	310	200	16	24.2%	16	29.4%	5%	8%
South Africa *[3]	48 000	62 000	2 772	15.1%	5 577	18.9%	6%	9%
Tanzania	15 500	14 500	1 044	10.3%	3 354	11.8%	7%	23%
Zambia	5 200	6 800	351	7.6%	575	8.6%	7%	8%
Zimbabwe *[3]	5 250	2 350	575	16.4%	1 576	11.3%	11%	67%
TOTAL	**114 579**	**114 281**	**9 875**	**22.0%**	**15 607**	**24.7%**	**9%**	**14%**

*[1] Including 3 700 agricultural engineers/agronomists.
*[2] Limited disciplines offered at local institutions. Overall numbers including those graduating outside the country will be higher.
*[3] Technologists not included – in these countries the qualification is offered at post-graduate level.

Legend	0-9% OK		10-15% A little high		>15 Excessive	

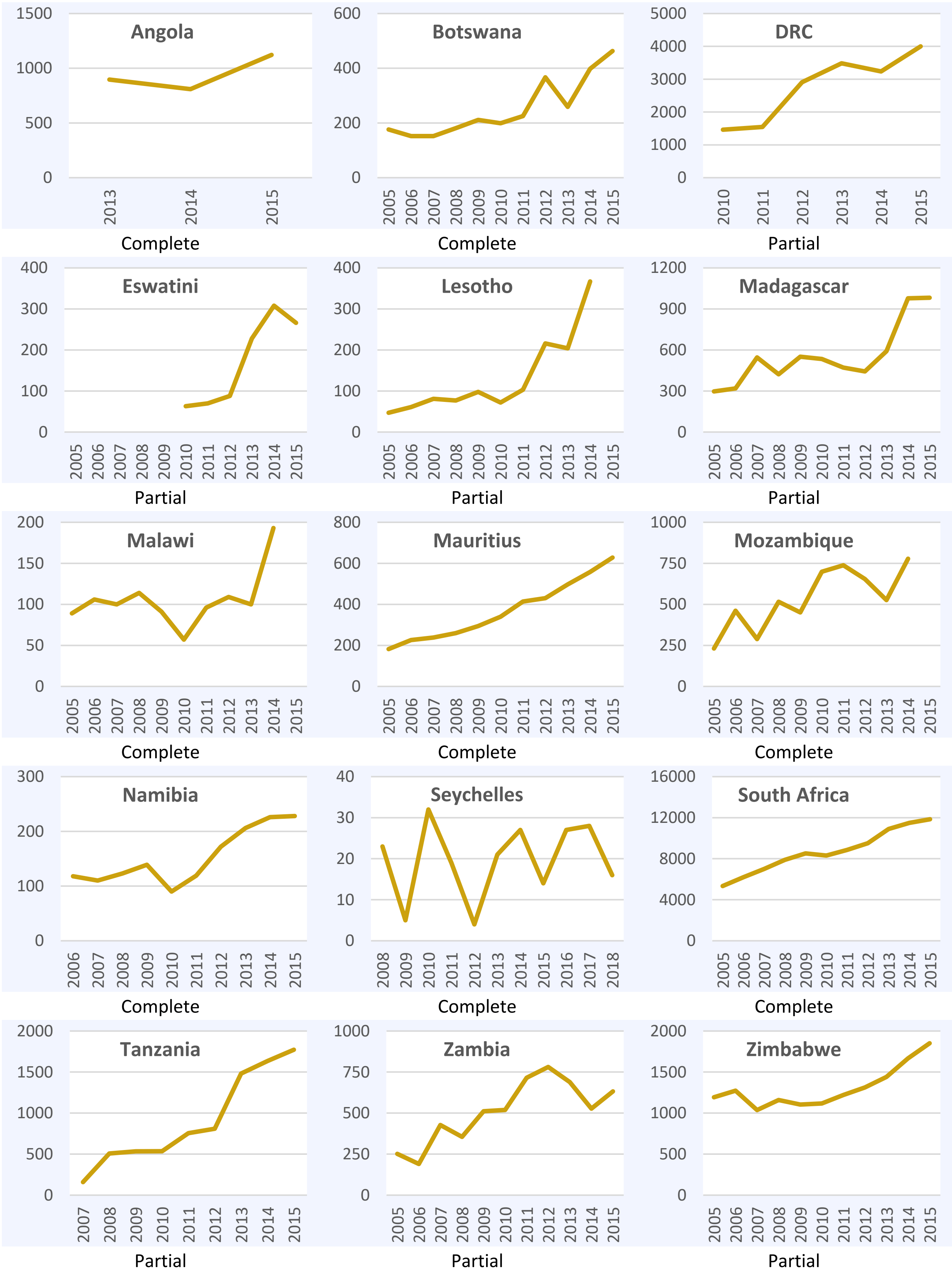


Figure 23: Graduation trends

In those countries with inadequate numbers of experienced local engineering professionals, external expertise and capacity may be required in the short to medium term, but such appointments must be linked to training and skills transfer to build an adequate base of local engineering skills, able to solve local problems in the future.

It should be noted that the scope of the current study was not a census of the engineering population in each country, but gives a high-level view. To determine exact numbers required per sector and industry needs per discipline, a detailed census per sector needs to be carried out. In time, each country should embark on its own detailed research to determine specific discipline requirements.

THE PROLIFERATION OF ENGINEERING PROGRAMMES

In recent years, countries have increased the number of public tertiary education providers, mainly to address regional needs, and have recognised private tertiary education providers. As a result, the number of courses offered has increased dramatically. Private education has become a commercial business, with student fees as the main source of income. For institutions to be viable, there needs to be a balance between students and academics. Where student numbers are low, this limits the number of academics employed, to the detriment of the education.

Each engineering discipline is composed of several subdisciplines. For instance, in civil engineering, structural, geotechnical, roads and transport, and water and sanitation are some of the many subdisciplines that must be covered, while in mining engineering, the range of minerals, underground, opencast, alluvial and other mining methodologies must be covered. Specialists in each subdiscipline or subject are required.

A study of staffing required in a civil engineering department, carried out some years ago, showed that a minimum of 18 academics were required to cover all the specialist subjects, and departments were not viable without at least 50 first year students per year. In many new universities, class sizes are very small, limiting the number of academics and the range of specialists available. As a result, the quality of graduates leaves a lot to be desired.

In other institutions determined to make a profit, only a handful of academics are employed to support thousands of students, who have been promised top-quality engineering education. In one institution there were only two full-time engineering academics to support 1 500 engineering students.

There is an urgent need to rationalise the number of tertiary education institutions offering engineering qualifications per country to ensure that the standard is upheld. Rigorous accreditation is required to approve programmes before universities, polytechnics and colleges should be allowed to take on large numbers of students. The support required per country is covered in detail in each country report.

THE NEED FOR CONSISTENT ACCREDITATION

The content and complexity of offerings vary enormously. Only South African higher education engineering qualifications are recognised under the Accords as outlined in Chapter 3. Educational specialists and industry players with a keen interest in the standard of education have been trained through ECSA’s agreement with the IEA on how to assess and accredit engineering qualifications to ensure equivalence.

Although assessors have found programmes to be equivalent at several institutions in the region, they have also found many degree courses to be equivalent simply to technologist qualifications, technologist courses to be equivalent to technician qualifications, and the theory associated with many technician courses to be equivalent to trade theory.

The number of tertiary institutions offering engineering qualifications is shown in Table 20, along with the differences in accreditation approaches.

The Accords cover the graduate attributes required for each category of engineering. Graduates need to have understood the theoretical underpinning of their chosen discipline or subdiscipline, and to become problem-solvers able to manage the type of work expected of their level of education. Accreditation bodies are expected to monitor and ensure that the appropriate standard is achieved. The attributes that are assessed are broadly:

1. **Knowledge:** Apply knowledge of mathematics, natural science, engineering fundamentals and an engineering specialisation according to the level of complexity required of an engineer, technologist or technician.

Table 20: Different accreditation approaches

(Number of institutions per country offering engineering qualifications)*

COUNTRY	No.*	ACCREDITING BODY	ROLE OF PROFESSIONAL BODY	RECOGNITION BY PROFESSIONAL BODY
Angola	16	National Institute for the Evaluation, Accreditation and Recognition of Higher Education Studies (INAAREES)	Not involved with the Department	Only recognises five-year degrees offered by public universities
Botswana	9	Botswana Qualifications Authority (BQA)	Works with BQA to review qualifications	Only recognises some of the qualifications as shown in the country report
DRC	123	Ministry of Higher and University Education Looks at resources and credits	Not involved	ACIC recognises qualifications from the Universities of Kinshasa, Lubumbashi, Goma and Mbuji Mayi
Eswatini	2	-	Newly formed professional body plans to accredit qualifications	The professional body recognises all categories of engineering professionals with accredited qualifications
Lesotho	2	Lesotho Council for Higher Education (CHE)	Works with CHE and educationalists from South Africa	NUL is being assisted by South African universities towards achieving Washington Accord provisional status
Madagascar	25	Ministry of Higher Education and Scientific Research (MESUPRES)	Works with MESUPRES to review qualifications	Only recognises five-year qualifications from public universities
Malawi	5	National Council for Higher Education (NCHE)	The Engineering Act requires the Board of Engineers to accredit qualifications	The professional body recognises all categories of engineering professionals with accredited qualifications
Mauritius	9	Tertiary Education Commission (TEC)	Works with TEC to review and approve qualifications. Only registers engineers with recognised local qualifications or accredited by the Engineering Council	An independent Engineering Accreditation Body (EAB) is being set up which is working towards provisional recognition under the Washington Accord, to be able to accredit local qualification
Mozambique	22	National Council for the Evaluation of the Quality of Higher Education (CNAQ)	Works with the CNAQ to review and approve qualifications	The professional body only recognises engineers from established universities
Namibia	2	Namibia Council for Higher Education (NCHE)	Works with the NQA to review and approve qualifications	The professional body recognises all categories of engineering professionals with accredited qualifications
Seychelles	1	Seychelles Qualifications Authority (SQA)	No professional body – being established	-
South Africa	14	Council for Higher Education (CHE)	Assigned responsibility for assessing qualifications	The professional body recognises all categories of engineering professionals with accredited qualifications, and is a signatory to the Washington, Sydney and Dublin Accords
Tanzania	17	Tanzania Commission for Universities (TCU) and the National Council for Technical Education (NACTE)	Serves on TCU and NACTE committees to review and approve qualifications.	The professional body recognises all categories of engineering professionals from established institutions
Zambia	10	Higher Education Authority (HEA) and the Technical Education, Vocational and Entrepreneurship Training Authority (TVETA)	Works with the HEA to review and approve qualifications. Several new universities offer qualifications but are not yet accredited	The professional body recognises all categories of engineering professionals with accredited qualifications, including artisans
Zimbabwe	12	Zimbabwe Council for Higher Education (ZimCHE)	Works with ZimCHE to review and approve qualifications	The professional body recognises engineers and technologists with accredited qualifications

2. **Problem analysis:** Identify, formulate, research literature and analyse engineering problems, reaching substantiated conclusions in line with the level of complexity required for the qualification.
3. **Design/development of solutions:** Design solutions of complexity, according to qualification-level requirements, for engineering problems, systems, components or processes that meet specified needs, with appropriate consideration for public health and safety, cultural, societal and environmental considerations.
4. **Investigation:** Conduct investigations of engineering problems of relevant complexity using appropriate research techniques to draw valid conclusions.
5. **Modern tool usage:** Select and apply appropriate techniques, resources and modern engineering and IT tools to engineering problems.
6. **The engineer and society:** Assess societal, health, safety, legal and cultural issues and the consequent responsibilities relevant to professional engineering practice and solutions to engineering problems.
7. **Environment and sustainability:** Understand and evaluate the sustainability and impact of engineering work in the solution of engineering problems in societal and environmental contexts.
8. **Ethics:** Understand and apply ethical principles and commit to professional conduct and responsibilities, and norms of engineering practice.
9. **Individual and teamwork:** Function effectively as an individual, and as a member or leader in diverse teams.
10. **Communication:** Communicate effectively on complex engineering activities with the engineering community and with society at large.
11. **Project Management and Finance:** Demonstrate knowledge and understanding of engineering management principles and economic decision-making, and apply these to own work, as a team member or a team leader.
12. **Lifelong learning:** Recognise the need for, and have the ability to engage in, independent and life-long learning in the broadest context of technological change.

The level of complexity set for each NQF level qualification will vary.

In many countries, the engineering body does not carry out accreditation. This is done by the qualification authority or the Department of Education or equivalent. This often means only ensuring that a range of subjects and adequate credits are included in the curriculum. The content, complexity and principles taught, student-to-staff ratios and quality or availability of laboratories or equipment are not interrogated in depth.

A SADC approach

The Accord standards should be adopted by all countries, and engineering bodies should be assigned the accreditation role. A compromise in standard may be necessary at the outset, but a minimum set of criteria should be agreed on initially, and a 10- or 15-year plan should be developed to ensure that over time all attributes can be achieved, and that qualifications produce the desired result.

CENTRES OF SPECIALISATION

Many countries have introduced new qualifications to address current needs, as discussed in Chapter 2. For instance, Angola has developed qualifications focusing on oil and gas. Others have started offering marine, textile and rail qualifications among others. The number of students who need to complete such qualifications is not high, but such specialisations are required. Collaboration between countries to decide on specialisations is needed and the requirements of all countries should be incorporated so that such qualifications are relevant for the region. Funding for the development of Centres of Specialisation, which can serve all countries, should be raised.

POST-GRADUATE TRAINING

Similarly, post-graduate specialisations should be debated and developed to cover regional needs. For instance, coastal, railway and harbour engineering have been highlighted as areas in which employees require more advanced knowledge.

REGIONAL KNOWLEDGE-SHARING

Other pioneering solutions have been developed which do not require full qualifications but rather short courses and hands-on training, such as the approach to wastewater recycling in Windhoek Municipality. Consideration needs to be given to exchanges between equivalent tiers of government to share knowledge and experience. There are bodies such as the Association of National Road Agencies (ASANRA) and the S.A. Independent Power Producers Association which share knowledge in the fields of roads and energy, but there does not appear to be a SADC grouping of municipal engineers.

STUDENT MOBILITY

Although most countries now have many institutions offering engineering qualifications, there is still significant student mobility for various reasons. Table 21 lists the some of the countries in which students choose to study.

Quality of education

Students travelling to other countries cite the quality of education as an important consideration. In 2015, there were a total of 52 878 SADC students enrolled in South African universities studying towards a range of qualifications, and 719 graduated with engineering qualifications. Students from many countries advise that they will have better job prospects when returning home with a South African qualification than a local qualification.

Qualifications and choice of discipline

In the smaller countries, universities do not offer the full range of engineering disciplines, or all levels of qualifications, hence the need to study outside the country. In these cases, governments at times offer bursaries to ensure that they have an adequate flow of engineering graduates returning to the country.

Foreign support

As part of bilateral agreements, foreign countries have offered free education for students from SADC countries, provided that the government pays the travel and accommodation costs. Although the offer of free education sounds attractive, the associated costs can be high. Furthermore, where tuition is offered in another language, students first need to spend a further year learning the language, adding to the costs and duration of study. In some cases, although the receiving country claims to be offering engineering degree studies, qualifications are not at the level expected and returning students find that their qualifications are not recognised by the local registering body. A coordinated effort is required between the departments responsible for arranging study grants and the departments that are the custodians of the registering bodies.

Table 21: Student mobility - country choices

COUNTRY	COUNTRIES FROM WHICH STUDENTS COME TO STUDY	COUNTRIES TO WHICH STUDENTS GO TO STUDY
Angola	Mozambique	Brazil, Canada, China, Cuba, France, Mozambique, Namibia, Portugal, Russia, South Africa, UK, USA, Zimbabwe
Botswana	Lesotho, Namibia, Zambia, Zimbabwe	Australia, Canada, China, Namibia, South Africa, UK, USA, Zimbabwe
DRC	Cameroon, Congo, Rwanda	Belgium, France, South Africa, USA
Eswatini	Zimbabwe	Russia, South Africa, Taiwan, USA, UK
Lesotho	Zimbabwe	Botswana, China, India, South Africa, UK, USA
Madagascar	Comoros and French-speaking countries, Namibia	China, France, Mauritius, Namibia, USA
Malawi	Mozambique, Zimbabwe	Australia, Kenya, South Africa, Tanzania, UK, USA
Mauritius	Burundi, India, Kenya Madagascar, Seychelles, Sri Lanka, Uganda	Australia, France, India, Malaysia, South Africa, UK
Mozambique	Angola	Algeria, Angola, Brazil, China, Cuba, India, Japan, Malaysia, Malawi, Portugal, Russia, South Africa, Tanzania, UK, USA
Namibia	Angola, Botswana, Kenya, Madagascar, South Africa, Tanzania, Uganda, Zambia, Zimbabwe	Austria, Cuba, Cyprus, Germany, Russia, South Africa, Tanzania, UK, USA, Zimbabwe
Seychelles	India	Australia, China, Egypt France, India, Malaysia, Mauritius, South Africa, UK
South Africa	All SADC countries, plus another 100 – refer to the HEMIS system for information	Australia, France, Namibia, Portugal, UK, USA
Tanzania	Mozambique, Namibia, Zimbabwe	Australia, China, India, Namibia, South Africa UK, USA
Zambia	Zimbabwe	Australia, Namibia, South Africa, UK, USA
Zimbabwe	Angola, Namibia	Australia, Canada, China, Cuba, India, Namibia, New Zealand, Russia, South Africa, UK, USA

RECOMMENDATIONS

A comprehensive academic experience is the foundation for developing engineering professionals. Much support is needed to enhance the quality of education. Specific recommendations are made in each country report. However, in general, the following need to be considered.

Schooling

- **Teachers:** the number of teachers needs to be increased to reduce the ratio of learners to teachers.
  - **Teacher training** needs to be expanded, and programmes to enhance the teaching of mathematics and science are required.
  - **Online learning platforms:** Schools need to be equipped with online learning facilities to increase the number of learners with access to quality teaching, and teachers need to learn how to facilitate large classes using new technology.
  - **Mobile service providers** should be approached to provide connectivity to schools.
  - **Funders and major employers** in the private and public sectors, should be approached to provide tablets and computer laboratories, or offer study rooms or areas where learners can access the internet and study on their own using corporate devices or their own devices.
- **High-calibre learners** need to be identified and given support to develop their full potential.
- **Subjects** need to be reviewed to ensure that they are relevant. Indigenous knowledge should be taught where relevant and subjects appropriate to localities, such as agriculture, need to be included as options when selecting vocational subjects.
- **Infrastructure needs to be upgraded, expanded and maintained**, including schools, classrooms, laboratories, libraries and associated resources. Practical and proven cost-effective school and classroom designs need to be shared in the region.
- **Resources,** including books, computers, laboratory and other equipment are required.
- **Career guidance** should be rolled out using a range of approaches, including videos, presentations, brochures and informative websites covering not only engineering disciplines, but also how to apply to tertiary institutions and access bursaries. Young role models in industry should be harnessed to visit schools where there are learners with potential. This should include reaching female learners, and those in rural and low-income areas.
- **Bursaries** are required where tertiary education is not free to attract learners who excel in mathematics and science to study engineering.
- **Studies outside the country:** Where engineering qualifications are not available locally, or capacity is limited, bursaries or support for students to study outside the country is necessary. It is, however, important that:
  - The international institutions selected offer qualifications that will be recognised by the local registering body when students return.
  - The numbers being supported are based on demand from industry and public sector structures.
  - Graduates are obliged to return to work in the country for a contract period, and funding is repaid should recipients not complete their contracts.

Tertiary education: Addressing throughput

A range of interventions is required to improve throughput.

- **Industry liaison:** Liaise with industry on a regular basis to ensure that curricula, methods, software and equipment are relevant, up to date and consider local conditions.
- **Curricula:** Provide funding to research, modernise and develop curricula and material where required.
- **Research:** Develop research and innovation capacity.
- **Teaching methods:** Apply the latest methods and technology for teaching, and train academics in 21st century approaches to teaching.
- **Facilities:** Raise funding to develop or upgrade lecture theatres, offices, libraries and laboratory facilities where required.
- **Resources:** Raise funding for computers, engineering software, access to online reference material, and laboratory and other equipment, and ensure adequate support to offer technology-relevant training.
- **Maintenance:** Budget for effective and continuous maintenance of equipment and facilities.
- **Optimal ratios of staff to students:** Determine optimal staff:student ratios to establish the number of additional academic posts required.
- **Attract and retain academics:** Improve conditions of service, support and packages to attract, retain and appoint additional academics.

  - Approach industry to subvent salaries or contribute to investment funds, professorial chairs and research students.
- **Academic development:** Provide funding for lecturer post-graduate development and facilitate opportunities for academics to gain experience in industry.
- **Administrative staff:** Ensure that adequate support and administrative staff are in place.
- **Retired professionals:** Approve the use of retired professionals to supplement the teaching load and act as mentors.
- **Part-time lecturers from industry:** Extend the use of industry experts to offer part-time or *ad hoc* lecturing.
- **Student support:** Expand tutoring support, summer and winter school interventions and the development of a buddy system to support students with the transition to the academic environment and, in many cases, city life for the first time.
- **Workplace experience:** Encourage industry to accommodate students requiring industrial attachments.

Tertiary Education: Alignment and rationalisation

To allow for mobility in the region, alignment of the accreditation of qualifications and quality assurance processes is essential. Rationalising the number of institutions offering engineering qualifications to ensure quality output will also be required.

- **A SADC Tertiary Education Engineering Education Committee (TEEEC)**, possibly a subcommittee under the TCCA, should be formed to consider qualification requirements and accreditation. This should be composed of academics and representatives from industry and accreditation bodies. Detailed research into industry requirements should be carried out per discipline, and findings must be fed into this committee to ensure that relevant solutions are developed.
- **Accreditation and quality assurance:** A consistent approach to accreditation is required. Ideally, professional bodies should be assigned the responsibility of accrediting or assessing engineering qualifications on behalf of the national quality assurance body to ensure that an appropriate range of subjects at the required level of complexity is offered.
- **Alignment of qualifications:** A common understanding of the role expected of technicians, technologists and engineers must be agreed and outcomes for each level of qualifications must be aligned, ideally using the graduate attributes of the Dublin, Sydney and Washington Accords as developed by the IEA.
- **Achieving the IEA standard:** The IEA attributes and accreditation model should be adopted as the benchmark. It will take several years for all countries to reach the same standard, but all institutions should be assessed and rated, and milestones should be set over 5, 10 or 15 years, or whatever is considered necessary to get all institutions up to the same standard. Some institutions may choose not to follow this approach. This would, however, disadvantage their graduates as they may not be registerable by the registering body in that country.
- **Rationalisation of enrolments and the number of institutions:** Norms and standards in terms of staff:student ratios, class sizes and minimum resourcing needs must be agreed. Where these cannot be met, approval for offering engineering qualifications should be withdrawn. Rationalisation of the number of students being enrolled and the number of institutions that can be sustained per country is also necessary.
- **Centres of Specialisation:** Collaboration must be facilitated when qualifications are being developed in specialist areas required only by a subset of countries to obviate the need for developing such qualifications in each country, especially where the numbers are small.
- **Post-graduate qualifications:** Coordination and collaboration are required for selecting appropriate topics and developing post-graduate qualifications.
- **Foreign studies:** The suggested TEEEC should play a role in advising governments on the suitability of qualifications being offered by donor countries.
- **Liaison with the Higher Education and Training, Research and Development Committee:** It will also be necessary to liaise with this committee to ensure that engineering qualification alignment requirements and recommendations are fed into the training and research agendas.

Graduate training

Worldwide employers have complained for many years about the difficulty in finding engineering skills. Without interrogating their statements, policy-makers have encouraged the opening of many more universities and the offering of many more engineering qualifications, only to find that the shortage of engineering skills persists.

It is evident from these statements that the difference between a scarce skill and a skills gap was not understood or perhaps inadequately articulated. A 'scarce skill' is one that is simply not available, whereas a 'skills gap' exists where there are qualified people, but they do not have appropriate experience. Employers are complaining about the lack of **experienced** staff. Experience is only developed in the workplace. The opening lines of the publication *Numbers and Needs* highlighted this problem back in 2005.

'Too few, too many.
No experience – can't get a job.
No job – can't get experience.'

The 'too few' referred to 'too few experienced' engineering staff, and the 'too many' referred to far 'too many inexperienced' graduates. The remaining two lines are obvious and must be addressed to overcome skills gaps.

Professor Peter Cappelli from the University of Pennsylvania considers that the skills gap is a myth. The real issue is that employers need to provide more on-the-job training.

THE UNEMPLOYED GRADUATE CHALLENGE

There is much to be considered in terms of the history of training, perceptions and bottlenecks.

THE DEMISE OF PAST PROGRAMMES

Graduates must be absorbed and trained in a structured manner before they can become useful to their employers. Such training was in place in public sector structures across the world until the late 1980s when outsourcing and unbundling were adopted.

Public sector structures which handled the entire process of conceptualisation, planning, design, implementation and operation and maintenance were ideal training grounds, and in many countries were the main structures in which training took place. When many of these functions were outsourced, graduate programmes were discontinued. Countries where this approach was widely followed have lost 20 to 30 years of growing their own experienced professionals, which is evident from the ongoing complaints of shortages.

The change in employment policies over the years has also impacted on appointing and developing graduates in the public sector. A lifetime career in the public sector was the norm, with graduates being trained and developed through the ranks, and promoted based on performance or as they achieved registration and other further education or training milestones. This is no longer the case, as it is necessary to apply formally for each post that falls vacant. Often the internal candidate is overlooked, thwarting development. Of concern in terms of the graduates' plight is that many public sector structures no longer have junior engineering posts.

Senker captures the challenge of training engineers when he suggests that governments and companies have not realised the importance of the workplace. He asserts that *'the quality and quantity of the learning opportunities afforded by experience at work are the primary factor affecting the quantity and quality of engineers' learning'*.

The large numbers of unemployed graduates must be absorbed and developed, and workplace training for future graduates must be catered for. At present it seems that, in general, only large consulting engineering companies which recognise the value of having more registered professionals, and some utilities and mining companies, have continued to offer comprehensive graduate training programmes.

EMPLOYMENT CHALLENGES

There are many reasons why graduates are unable to find work, the most important of which are:

- **Oversupply:** The supply greatly exceeds the demand for graduates in many countries.
- **Limited projects:** Organisations cannot afford to take on graduates unless they have enough work, which has become a problem in tough economic times.
- **Quality:** The quality of graduates leaves a lot to be desired and organisations select only the best to employ and train.
- **Not career ready:** Companies consider that graduates should be career ready like the medical profession or teachers, and wish to employ only experienced professionals, but do not consider the years of internship covered in the qualifications of the other professions. (It should be noted, however, that the cost of

internships for the medical and education professions are borne by the state in teaching hospitals, etc.)

- **Competitive bidding:** Companies cannot afford to train graduates. The latter has come about because governments have delegated training to the private sector, at the same time expecting the sector to compete for work at rock-bottom prices.
- **International service providers:** Most large projects have been awarded to international consultants and contactors. The latter rarely appoint local staff, let alone train graduates.
- **No junior posts:** In many countries there are no junior posts in the public sector, or legislation prescribes that only registered professionals may be appointed. This precludes recent graduates from joining the public sector.
- **Moratorium on employment:** In several countries there is a moratorium on employing new staff in the public sector.
- **Inappropriate qualifications:** Graduates returning from studying overseas may find that their qualifications are not recognised in their home country.

GRADUATE EXPERIENCES

The fortunes of graduates vary across the SADC region, depending on the percentage of graduates, the quality of higher education and the development taking place in the country.

Unemployed graduates are an exasperated group of young people, a large percentage of whom have had very frustrating experiences trying to enter the workplace, and often don't get meaningful work once appointed.

In many countries appropriate posts are not advertised. Out of desperation, graduates send their CVs to hundreds of employers, and often do not get a single response. They therefore take employment outside of engineering and the longer they are out of engineering, the more difficult it is to find an engineering post. Others start their own businesses outside of engineering, never to return.

As a matter of interest, some Member States reported that unemployed graduates make good mathematics teachers. The TeachFirst initiative in the UK has recognised the value of using those with undergraduate qualifications to enter the teaching profession and offer intense short-term training to help graduates transition into teaching – perhaps something similar should be offered in the region.

Graduate engineers also apply for technician posts in the hope of eventually being able to move into an appropriate post when it becomes vacant, thus precluding technicians from filling the limited number of posts available.

Employers take advantage of the oversupply, pay very low wages and at times use graduates to carry out menial tasks not related to engineering.

Due to limited opportunities locally, the brightest graduates apply to do post-graduate studies in other countries and once they have proved their worth in host countries, do not return home.

Many try their luck at applying for posts outside the country, but generally only those who come from respected and long-established institutions are successful.

SUPERVISION CAPACITY

The reality is that the major part of an engineer's training is in the workplace, working on real projects under the guidance of experienced supervisors who act as coaches, ensuring skills transfer. In a structured environment, a mentor would also be assigned to the training phase to monitor progress and ensure that in the long term the graduate has gained a range of experience of increasing complexity, and has been given the opportunity to take increasing responsibility and make decisions under guidance.

Supervisors and mentors, however, also have their own roles to play in terms of leading projects, monitoring progress and liaising with stakeholders, among others, and only have limited time to spend with each staff member who reports to them. The growth in the number of graduates reflects the increasing number of those under 35 in most SADC countries. Table 22 shows the ratio of 25 to 34-year-olds to the supervisor/mentor age group of 35 to 64. In some countries, the number of 25 to 34-year-olds is more than 70% of the number of 35 to 64-year-olds. In Africa the average is 69% as against the world average of 47%. This presents a huge challenge in terms of training capacity. In Europe the ratio of younger to older is as low as 33% and in North America it is 35%. The ratio is higher in South America at 48% and in Asia it is 47% – but both are substantially lower than the African ratios.

Many countries advised that a significant number in the 35 to 64 age group were nearing retirement and complained of the phenomena of the 'missing middle' i.e. few engineering practitioners between their late thirties and early fifties, which can be seen in the engineering population pyramids, plotted in

Table 22: Percentage per age group

REGION	COUNTRY	PERCENTAGE PER AGE GROUP				RATIO OF 25–34 TO 35–64
		0–24	25–34	35–64	>=65	
SADC	Angola	66.2%	13.3%	18.2%	2.3%	73%
	Botswana	51.2%	18.9%	26.2%	3.7%	72%
	DRC	65.2%	13.1%	18.7%	3.0%	70%
	Eswatini	60.3%	17.9%	18.7%	3.1%	96%
	Lesotho	57.9%	17.7%	20.0%	4.4%	88%
	Madagascar	62.1%	14.1%	21.0%	2.8%	67%
	Malawi	65.6%	14.6%	16.8%	3.0%	87%
	Mauritius	35.1%	14.0%	40.9%	10.0%	34%
	Mozambique	64.9%	13.5%	18.5%	3.1%	73%
	Namibia	58.4%	15.8%	22.3%	3.5%	71%
	Seychelles	34.9%	15.8%	41.1%	8.2%	38%
	South Africa	48.0%	17.8%	29.2%	5.1%	61%
	Tanzania	64.6%	13.8%	18.5%	3.1%	75%
	Zambia	66.0%	14.3%	17.2%	2.5%	83%
	Zimbabwe	62.2%	16.9%	18.1%	2.8%	93%
World and Continental Averages	SADC	57.5%	15.4%	23.0%	4.0%	67%
	World	42.3%	15.8%	33.6%	8.3%	47%
	Africa	60.3%	14.8%	21.4%	3.5%	69%
	Asia	40.8%	16.5%	35.2%	7.6%	47%
	Europe	26.8%	13.9%	41.7%	17.6%	33%
	Northern America	32.6%	13.7%	38.9%	14.8%	35%
	South America	41.4%	16.5%	34.1%	8.0%	48%

Legend	0-40% OK	41-65% High	>65% Excessive

country reports. The ratios of junior to senior engineering practitioners are thus likely to increase in the next few years.

There are simply not enough of the experienced age group with adequate time to devote to the development of young people, if traditional workplace skills transfer methods are the only methods used. Techniques such as Action Learning, pioneered by Revans after World War II when the ratio of senior to young staff was also very low, should be considered. The Revans approach advocates group learning on actual projects where the subjects *'learn with and from each other by mutual support, advice and criticism during their attacks on real problems'*. This approach has been used successfully in MBA programmes for many years.

Given the big infrastructure projects planned in many SADC countries, there is no reason why graduates cannot be appointed in groups and given a range of tasks to solve together. In this way they will learn from each other as well as from the line manager assigned to supervise and manage their development. Similarly, considering industrial development, groups need to be part of setting up production lines and systems, and need to learn together about managing processes and enhancing productivity.

As employment is no longer for life, developing versatile professionals is important. Those responsible for training groups should share rules of thumb to allow graduates to make judgement calls, and should set challenging tasks and assignments to develop problem-solving skills. However, it is not every experienced engineering professional who considers that it is his or her duty to train graduates. Two approaches need to be considered in this regard:

- Making graduate training a key performance area for seniors
- Appointing external, possibly retired, staff to oversee groups being assigned to projects, under the direction of the line manager.

GRADUATE DEVELOPMENT

Clearly, many factors must be in place for effective development to take place. These include:

- **Commitment:** The employer, graduates-in-training, supervisors, mentors, and managers involved must be committed for graduate programmes to be successful.
- **Orientation:** An orientation session should be convened to explain the requirements of the

registering body, the roles players, activities and programme and what is expected of graduates.

- **Plan:** A plan should be drawn up to ensure that graduates are exposed to a variety of engineering activities and that the outcomes expected by industry and the registering body will be achieved.
- **Projects:** There should be suitable projects on which to gain experience, which will allow graduates to take increasing responsibility and learn how to solve increasingly complex problems. Where the range of such projects is limited, rotation to other departments, or secondment to other organisations should be considered.
- **Supervision and coaching:** There must be experienced line managers, with sufficient time to supervise and coach graduates.
- **Resources:** Appropriate tools and equipment, including computers, software and protective gear, among others, must be available.
- **Support systems:** There must be access to reference material and a community of practice to whom graduates may refer for additional input and support.
- **Reporting and reviewing:** Graduates should report on the work they have carried out and progress should be reviewed on a regular basis.
- **Mentoring:** A mentor must be assigned to monitor progress, challenge graduates and select additional or alternative engineering activities where necessary. The mentor may also be the supervisor, but must recognise his or her role to monitor the graduate's long-term progress, as well as the day-to-day tasks carried out under his or her supervision.

Recognising the need to re-implement formal programmes, countries have started to develop structured or national approaches which should be used to create guidelines for a regional model. The most substantial programmes are outlined below.

TANZANIA

The Structured Engineers Apprenticeship Programme (SEAP), as outlined in the Tanzania report, spells out the need for funded, structured training programmes to develop tomorrow's professionals. The programme was launched by the Minister of Works, Hon John P. Magufuli, in January 2003 and is supervised by the Engineers Registration Board (ERB). It aims to enable Tanzanian graduate engineers to qualify for registration as professional engineers in the shortest possible time. The ERB monitors progress, engages with mentors and reviews quarterly reports.

After extensive consultation, a detailed programme implementation document was developed which covers among others:

- Competence standards to be achieved
- The requirements for employers
- Roles and responsibilities for all parties
- Suggested training activities per discipline
- Supervision and monitoring
- The use of a logbook and monitoring requirements
- Assessment methods
- Various contract documents and agreements between the ERB, employer and graduate.

Of importance is the list of activities suggested per discipline. Although comprehensive, the list is not prescriptive, and recognises that experiences will vary per sector and type of industry, even for the same discipline. Achievement of the outcomes is the ultimate aim. It is thus suggested that appropriate activities should be selected per employer to make up the training plan.

This principle is important when developing any training programme, as it will not be possible in any one environment for graduates to gain experience in the range of activities associated with their discipline within the first few years of their careers. Given that the guidelines were developed some 15 years ago, additional disciplines need to be added to the guideline, and the outcomes should be aligned to those of the IEA, although many are essentially the same.

In the early 2000s the programme focused on placing graduates in government, but as funding has been reduced, the private sector has taken over funding and offering placements. Since 2003, a total of 5 300 graduates have been taken on, of whom just over 2 000 graduates had been supported by the private sector since 2015. The public sector training posts are now reserved for female students, who are taken on with the assistance of foreign funding. Although graduate training has increased, it is estimated that only half of the graduates are trained through SEAP.

SOUTH AFRICA

In South Africa, the *Training Standard* was gazetted by the Construction Industry Development Board (cidb) in 2013. If appended to a tender, it compels service providers to make provision in their tenders to train apprentices, students and graduates. Requirements include the provision of a training plan, logbook or reporting template, an experienced supervisor who will assign tasks and coach graduates, and a mentor who will monitor progress and intervene when experience being offered is inadequate.

A structured approach to training has been re-implemented by several parastatals, large infrastructure departments and metropolitan municipalities. These organisations take on graduates and generally follow relatively rigid programmes, which in some cases are not demanding enough as complex work is outsourced to consultants and contractors.

A graduate being developed towards professional registration is known as a candidate. Candidate training has been recognised as a learning pathway where *'candidacy means a period of workplace-based learning undertaken by a graduate as part of the requirement for registration as a professional in the required professional designation as stipulated by a professional body'*. Employers may access funds from the Sector Education Training Authorities (SETAs) for candidate training beyond public sector projects.

There is a need for the CIDB Training Standard to be made mandatory on all public sector projects.

MAURITIUS

In 2014, to try to address the unemployed graduate challenge, the Ministry of Labour, Industrial Relations and Employment has created the Youth Employment Programme (YEP). It is possible for graduates to apply for support, or for companies to approach the YEP for suitable graduates to take on for a period of two years. During this period, the employer is expected to train graduates towards the competence expected of their profession. The programme pays the stipend for graduates if employed in the public sector, and 50% of the stipend if in the private sector. The YEP also contributes towards the costs of supplementary training during the period, as long as it is recognised by the Mauritius Qualifications Authority (MQA).

The challenge is to ensure that graduates follow a structured programme of meaningful work to achieve the outcomes expected by the Council of Registered Professional Engineers (CRPE). It is important that mentors are in place to monitor the process. The Institution of Engineers Mauritius (IEM) is busy designing graduate training programmes for the industry to use, to ensure that graduates are given appropriate experience.

ZAMBIA

In Zambia, although it does not address graduate training, the Copperbelt Energy Corporation has stepped in to assist with making students more career-ready. Recognising that academia cannot compress engineering fundamentals, changing technological and industry needs into undergraduate programmes, they have constructed a complete power system (composed of two substations and a transmission line complete with a control system) at the University of Zambia's School of Engineering. They have also supported the development of a curriculum in solar energy technology at the Copperbelt University as part of their recently constructed 1 MW solar photovoltaic power plant.

They also support students in the annual Shell Eco-Marathon in which they are challenged to design, build and drive the most energy-efficient car, and they offer internships to make students more employable upon graduation. Many more companies should be encouraged to follow suit.

OTHER SECTORS AND THE UTLITIES

In many countries one or more utilities are still offering structured training in some form or another, while in Angola companies are called upon to submit and have their training plans approved to access training funds made available from the sale of oil.

Of concern is the fact that limited training is seen in the private sector in areas such as manufacturing, ICT, consulting and mining in some countries.

In the words of Professor Cappelli *'… employers… must be deeply involved in the process of skills development—just as they were in the past. But how can we get decentralized employers to help provide work-based learning experiences in some structured way for people who are not already their employees? That seems to be the challenge, and it's a big one.'*

RECOMMENDATIONS

Investment in tertiary education will not achieve the engineering capacity desired without following through and ensuring that funds are invested in graduate training. Methodologies for funded, structured training must be developed and agreed upon, emerging from this study. The large numbers of unemployed graduates must be absorbed and developed to become the experts of the future.

Graduate training

- **A regional committee** should be formed under the SADC Technical Committee on Higher Education, Training, Research and Development composed of employers and professional bodies, who have been successful with graduate training. The committee should develop graduate training guidelines for the region to ensure that graduates achieve the level of competence required by industry and for professional registration.
- **Guidelines** should include an overview of the variety of engineering activities that could contribute to graduate development, along with all the elements listed under the section titled *Graduate Development,* such as:
  - Committed employers, graduates, supervisors, mentors and managers, and suitable engineering activities or project on which to gain experience
  - Approaches to developing and updating training plans
  - Supervision, coaching and mentor roles, requirements and techniques
  - Resources and support systems required
  - Reporting and reviewing mechanisms, etc.
- **Management and structure:** Programmes should be managed by engineering professionals and should include the opportunity for rotation or secondment where appropriate experience is not available in existing positions. Graduates must also be afforded the opportunity to take on increasing responsibility and increasingly complex work.

The committee will need to consider and propose various options, allowing for flexibility and adaptation by employers, as experience per discipline and sector varies and no two workplaces are alike.

Training opportunities

Approaches to ensure that every '*engineering workplace becomes a training space*'[2] need to be considered.

- **Private sector incentives:** Offer tax rebates or incentives for private sector service providers such as consultants and contractors to develop graduates.
- **Public sector support:** Ensure that public sector structures take on and train graduates, and that they are absorbed and developed through the ranks.
- **Institutional support:** Institutionalise graduate training in all organisations by setting KPIs for experienced staff to act as supervisors and mentors.
- **Project support:** Make graduate training a requirement of all public sector projects and ensure that the progress of graduates is monitored, and penalties are imposed for non-compliance.
- **Industrial development support:** Offer tax rebates or incentives for local industrial companies to develop graduates or make graduate training a condition of offset agreements in the case of international investors developing local industries.

Promotion and support

Once adequately designed and documented, professional bodies should become the vehicles for promoting such programmes, advising on them and assisting with access to mentors, as well as training employers, mentors and candidates alike on what is expected of them in the first few years of a graduate's career.

[2] This is a phrase coined by Minister Blade Nzimande when he was the Minister of the Department of Higher Education and Training in South Africa.

Chapter 9

Professional registration

The science of modern-day infrastructure, such as surfaced roads, railway networks, waterborne sewage removal, piped potable water and, later, electrification, as outlined earlier in the report, only emerged in the late 18th century and needed to be shared by the pioneering masters with their peers to ensure that the technology was widely adopted and implemented.

In 1818, an exuberant group of young pioneers recognised the need for a structured method of sharing information and formed the London-based Institution of Civil Engineers for the purpose of *'promoting the acquisition of that species of knowledge which constitutes the profession of a civil engineer'*. Over time, institutions or 'learned societies', as they were known, sprang up worldwide with the goal of sharing knowledge; they are still leaders in sharing information and technological advances today. One of the first institutions to be formed in the SADC region was the South African Institution of Civil Engineering which was formed in 1903. Many others followed as purely 'Voluntary Associations', a term which is in common usage. There are several VAs in each SADC country, addressing discipline and/or sector interests, although some are not very active, or have been dormant for some time. Details of all the VAs are covered in the country reports.

PROFESSIONALISATION

In the 1920s a change in approach to corporate membership of institutions began to emerge in the UK and the USA. Simply practising in the field did not ensure the competence and associated high standards that were considered important. Many institutions introduced professional exams and licensing. The London-based Institutions of Structural Engineers and Civil Engineers introduced their exams in 1920 and 1932 respectively, and in the USA, the Californian Structural Engineers became one of the first to introduce professional registration and 'licensing' exams in the 1930s. Structural engineering received early attention due to the obvious threat to public safety in the event of unsatisfactory designs, and in California, in particular, due to the behaviour of structures during earthquakes.

More recently, licensing has become the domain of statutory bodies. In the UK, the Engineering Council was formed in 1982 as an outcome of the Finniston Report which investigated the responsibility and status of engineers in the UK. The Engineering Council took to moderating exams set by the Institutions and issuing the Chartered status required for independent practice. These bodies are referred to as Registering Bodies (RBs).

Mauritius was the first country in the region to form a statutory body. Amendments to the Private Bill governing the Institution of Engineers Mauritius (which was formed in 1934) were submitted to parliament for consideration. The Select Committee recommended that a statutory body be set up for this purpose, hence the emergence of the Council of Registered Professional Engineers (CPRE) in 1965. Tanzania and South Africa followed suit in 1968, with the formation of the Engineers Registration Board (ERB), Tanzania, and the South African Council of Professional Engineers (SACPE) respectively. SACPE has since become the Engineering Council of South Africa (ECSA). Both are statutory bodies responsible for registering engineering professionals.

By the early 2000s, there were 10 registering bodies in the SADC region. In 2009, 2013 and 2018, registration Acts were promulgated in Botswana, Eswatini and the DRC respectively (see Table 23 to 23). As the Act associated with l'Ordre National des Ingénieurs Civils (ONICIV) was only promulgated in the DRC on 13 December 2018, details were not available to include in this report.

Most statutory bodies fall under the Ministry or Department of Public Works or Construction in each country. These ministries or departments may also have set up statutory bodies to regulate contractors, and in some instances consulting engineering practices. In South Africa and Tanzania, overarching bodies have been RBs. In South Africa, the Council for the Built Environment (CBE) was set up under the CBE Act. It oversees the RBs for engineering, architecture, landscape architecture, quantity surveying, construction project management and construction management, and property valuations. In Tanzania, the National Construction Council (NCC) was set up under the NCC Act. It oversees the RBs for engineering, contracting, architecture and quantity surveying.

CATEGORIES OF REGISTRATION

Details of the categories of registration per country are shown in Table 23. Eswatini, having a small population, has elected to set up one RB for all built environment professionals. Lesotho is in the process of finalising a registration bill in which they have adopted a similar approach. The Seychelles is also developing a registration bill.

Table 23: Registration categories and criteria per country, 2018

COUNTRY	Graduate engineers	Graduate technologists*	Graduate technicians	Professional engineers	Professional technologists*	Professional technicians	Temporary professional engineer	Minimum period to professional registration	Other categories
Ordem dos Engenheiros de **Angola** (OEA)	-	-	-	√	√ TE	-	-	After graduation	√
Engineers Registration Board, **Botswana** (ERB)	√	√	√	√	√	√	<1 year	4 years	Registered Engineer, Technologist, Technician
l'Ordre National des Ingénieurs Civils, **DRC** (ONICIV)	√	-	-	√	-	-	Unknown		-
Architects, Engineers, Surveyors & Allied Professionals Registration Council of **Eswatini** (AESAP)	√	√	√	√	√	√	√	3 years	Certificated Engineer Professional Architect, Surveyor and Allied Professional
Ordre des ingénieurs de **Madagascar** (OIM)	√	-	-	√	-	-	-	1 year	-
Board of Engineers, **Malawi** (BoE)	√	√	√	√	√ TE	√	-	1–3 years	Selected Registered Engineer
Council of Registered Professional Engineers of **Mauritius** (CRPE)	√	-	-	√	-	-	√	2 years	-
Ordem dos Engenheiros de **Moçambique** (OrdEM)	√	-	-	√	-	-	-	2 years	-
Engineering Council of **Namibia** (ECN)	√	√ IE	√	√	√ IE	√	√	3 years	-
Engineering Council of **South Africa** (ECSA)	√	√	√	√	√	√	-	3 years	Certificated Engineer, Specified Category
Engineers Registration Board, **Tanzania** (ERB)	√	√ IE	√	√	√ IE	√	√	3 years	Registered Consulting Engineer
Engineers Registration Board of **Zambia** (EngRB)	√	√	√	√	√	√	√	2 or 4 years	Registered Craftsperson
Engineering Council of **Zimbabwe** (ECZ)	√	-	√	√	-	√	√	3 years 2 years for technicians	-

* Professional technologists are known as Technical Engineers or Technician Engineers (TE) or Incorporated Engineers (IE) in some countries

From Table 23 it can be seen that countries have adopted different approaches. Initially, most Acts only catered for the registration of engineers. Amendments, as listed in Table 25, have generally included additional categories, recognising that the engineering team comprises several levels of engineering practitioners, each responsible for different elements of engineering projects. However, not all countries offer tertiary education qualifications covering the three categories considered in this study.

It should be noted that the development of competent engineering practitioners is a two-step process, whereby professional registration is the summative assessment of the competence developed in the education and workplace phases (known as Stage 1 and Stage 2 in the IEA documentation). This applies to the registration of engineers, technologists and technicians, but may be different in some of the other categories.

Other categories of registration

As can be seen from Table 23, there are several other categories that have been accommodated by various bodies.

- **Craftspeople:** The inclusion of craftspeople by the Zambian EngRB is a departure which needs to be debated. The structure of craft training is substantially different from that of engineering

practitioners in that the bulk of training is hands-on through an apprenticeship in a workplace. Before being certified as a craftsperson, or tradesperson, learners must undergo a summative assessment which largely assesses their ability to build or repair the equipment, machinery or infrastructure relating to the field. This means that crafts- or tradespeople have already effectively been registered. If registering bodies are going to adopt these categories, it will be necessary to decide what role they should be playing in terms of ensuring standards.
If the call for registration has arisen as the quality of artisan training has declined, then the causes must be addressed. If the requirement for registration persists, registering bodies will need to have access to workshops, tools, material and master artisans to carry out appropriate assessments.

- **Certificated engineers** as registered by ECSA are practitioners who have a Government Certificate of Competence under the Mining or the Factories Acts and are responsible for health and safety management on large mechanical or electrical installations. Before registration they must have taken responsibility for such installations for at least two years.
- **Specified categories** relate to master artisans or specialist operators responsible for items of equipment that could be hazardous to public health and safety if they are not adequately calibrated or maintained, such as Lift Inspectors, Lifting Machinery Inspectors and Medical Equipment Maintainers.
- **Selected registered engineers** as recognised by Mauritius refers to experienced registered engineers who have been nominated to supervise and develop graduates towards professional registration.
- **Registered engineers, technologists and technicians** in Botswana refers to an additional level of registration whereby applicants who are found to have inadequate experience for registration as professionals, but who have had three or more years of experience, are given interim registration. They are required to return for re-assessment once they have had sufficient experience to satisfy the outcomes prescribed. However, many simply use the ERB registration certificate reflecting the category ‘Registered’ to show that they are registered, and clients without intimate knowledge of the ERB system believe that this certification signifies a competent professional. The ERB are considering withdrawing this category of registration.

Registration of graduates

There are varying approaches to the registration of graduates. In some countries, graduate registration is not a prerequisite for professional registration but is voluntary. The term ‘candidate’, or ‘graduate-in-training’, or the specific category-in-training, such as ‘engineer-in-training’ or ‘technician-in training’, is used.

In other countries such as Zambia and Tanzania, registration of graduates is compulsory. They are given a grace period after being employed by which time they must have registered. In Namibia, they must first register with the ECN before they can apply for a job, which can delay their opportunities for employment.

ASSESSMENT AND REGISTRATION

Professional registration is a measure of competence and the ability of graduates to work independently. The International Engineering Alliance (IEA) has developed attributes for what is expected of registered professionals per category, to allow the mobility of professionals. In the SADC region, there is disparity in approaches to professional registration, which requires consideration.

ASSESSMENT

Although assessment takes place, in some countries the measure for registration is simply the time spent in a workplace after graduation, while in other countries there is a rigorous approach to assess the complexity and quality of work carried out. Detailed reports must be submitted, and applicants are interviewed or must write an exam. The structure of detailed reports and the assessment of what is required of a professional, however, also vary.

The IEA attributes require that a person ready for registration should be able independently to:

1. Comprehend and apply knowledge of complexity relevant to category of registration, which underpins good practice
2. Comprehend and apply knowledge specific to the jurisdiction of the area of practice
3. Define, investigate and analyse engineering problems
4. Design or develop solutions to engineering problems
5. Evaluate the outcomes and impacts of engineering activities
6. Recognise the reasonably foreseeable social, cultural and environmental effects of activities,

consider the need for sustainability, and recognise that the protection of society is the highest priority
7. Meet all legal and regulatory requirements and protect public health and safety in the course of engineering activities
8. Conduct activities ethically
9. Manage part or all of one or more engineering activities
10. Communicate clearly with others in the course of engineering activities
11. Undertake CPD activities sufficient to maintain and extend competence
12. Exercise sound judgement in the course of engineering activities and choose appropriate solutions
13. Be responsible for making decisions on engineering activities.

There is always the danger that applicants did not complete their own application forms or were given substantial assistance to complete their forms. Interviewing applicants or setting professional exams offers the opportunity to determine whether applicants have performed to the level as outlined in their submissions and whether they can think on their feet. The disadvantage of interviews is the time required for professionals to devote to interviews, but it does allow the applicant's ability in his or her practice area to be thoroughly scrutinised and the opportunity to test high level-thinking, problem-solving and creativity, as outlined under Bloom's Taxonomy in Chapter 3, *Developing professionals*. The disadvantage of professional examinations is the difficulty in being able to cover the practice areas of all applicants, hence the pass rate for professional exams tends to be lower than that for the interview process.

As part of the registration process, all professionals are expected to abide by the Code of Conduct of the respective body. Most Codes of Conduct are similar and expect professionals to act with integrity and not perform work other than that for which their education, training and experience has rendered them competent. The applicant's understanding of ethical issues must be interrogated when attending the professional interview.

As part of the preparation for professional registration, many countries have included the requirement for Initial Professional Development (IPD). This requires that graduates grow their knowledge and skills through self-study, and by attending courses, workshops and conferences as required. This is not limited to technical development, but covers any skills required to grow as a professional, which could include the use of software, public speaking, etc. IPD has been introduced not only for development during the graduate training phase, but also to develop the culture of life-long learning.

Consideration should be given to alignment of the registration process in the region, including interviews and assessments based on the IEA attributes.

Table 24: Numbers of candidates and professionals registered (only 12 countries)

COUNTRY	CATEGORY								METRICS		
	GRADUATE/CANDIDATE-IN-TRAINING				PROFESSIONAL				COMPARISONS		%
	Engineer	Technologist	Technician	Certificated	Engineer	Technologist	Technician	Certificated	Total professional	Engineering workforce	% professionally registered
Angola	506	-	-	-	3 337	-	-	-	3 337	9 000	37.1%
Botswana *	1 542	297	1 201	-	1 272	123	357	6	1758	6 000	29.3%
Eswatini	12	3	17	2	36	6	6	-	48	1 600	3.0%
Madagascar	-	-	-	-	765	-	-	-	765	11 000	7.0%
Malawi	-	-	-	-	706	423 TE	163	-	1 292	3 200	40.4%
Mauritius	-	-	-	-	851	-	-	-	851	5 000	17.0%
Mozambique	1 225	-	-	-	1 868	-	-	-	1 868	11 000	17.0%
Namibia	452	321 IE	197	-	506	201 IE	102	-	809	2 800	28.9%
South Africa	7 749	4 385	6 674	281	15 862	5 513	3 921	966	26 262	110 000	23.9%
Tanzania	9 428	661	-	-	5 699	409	-	-	6 108	30 000	20.4%
Zambia	-	-	-	-	2 066	566	483	-	3 115	12 000	26.0%
Zimbabwe	-	-	-	-	1 754		473	-	2 227	7 600	29.3%
TOTAL	**20 914**	**5 667**	**8 089**	**283**	**34 722**	**7 241**	**5 505**	**972**	**48 440**	**209 200**	**23.15%**

*Candidates includes those in the Registered, but not Professional categories

Comprehensive workplace training and adequate exposure to a sufficient range of experiences is thus required to prepare graduates for such assessments. The scope of workplace training and registration requirements were outlined in Chapter 8, along with the associated challenges of gaining adequate workplace experiences.

REGISTRATION

Different types of registration are in place. In Angola and Madagascar, graduates are not professionally registered in the manner carried out by other registering bodies, but rather those graduating from accredited institutions are granted a 'licence' to enter the engineering workplace. If the region works towards a uniform accreditation process for all engineering qualifications as discussed in the previous section, this approach should be replaced with the more rigorous approach of assessing workplace competence.

Both countries, plus the DRC, the Seychelles and Lesotho, are looking at implementing professional registration systems and need support in this regard.

FUNCTIONALITY PER BODY

There are several other differences in the various Acts, as shown in Table 25, as discussed below.

RECOGNITION OF PRIOR LEARNING (RPL)

Very few Acts make provision for the recognition of prior learning (RPL). RPL recognises that practitioners could have achieved the knowledge and practical competence by experience rather than through a combination of qualifications and experience. This normally applies to older practitioners, or those who have studied and gained experience in countries where the structure of engineering education and training is different from the structures in the region. Detailed analysis of work done, and the knowledge gained, is assessed to determine equivalence to registration requirements. Documenting experience to demonstrate competence via RPL is very demanding and assessments are extremely rigorous. However, the process is worth considering to ensure that those who are competent can be recognised and can contribute to the engineering workforce.

RECOGNITION OF FOREIGN QUALIFICATIONS

In the absence of the Accords applying worldwide, it is difficult to determine whether applicants with foreign qualifications have received an education on par with the local qualifications required for professional registration. Several countries have developed a register of those qualifications which they recognise, but do not have streamlined mechanisms for assessing qualifications from other higher education institutions. In the absence of receiving a transcript of the courses covered, the projects and problem-solving undertaken, and the lecturing capacity and laboratory facilities in place, it is difficult to assess equivalence. Some countries do not accommodate these assessments.

Other countries require all the documentation listed to be validated by the SADC country's embassy in the country of study before they will assess them. Where there is no embassy in the country of study and documents must be sent to the embassy in another country for validation, the process can takes months or years, or not happen at all. It is essential that mechanisms are established for the recognition of qualifications gained in other countries.

Registering bodies also need to work with ministries on the choice of countries and institutions to which students are sent to study overseas. Although receiving countries offer free tuition, the countries sending the students must pay travel and accommodation costs. It has been found in several instances that returning students have discovered to their dismay that the qualifications they have gained do not match the requirements of their country's registering body.

When considering the world ranking of countries in terms of GDP per capita, or the ranking of higher education institutions, it has been found the students are at times sent to countries which are weaker financially, and to institutions of lower ranking than in their home country. These returning graduates struggle to compete with those who studied locally.

CONTINUING PROFESSIONAL DEVELOPMENT (CPD)

To keep up to date with the latest technologies, methodologies and legislation, it is essential that professionals learn from experts at the cutting edge, have access to the latest documentation, and attend courses and workshops to expand their knowledge. CPD is the life-long process by which professionals enhance their knowledge and skills to complement their current role and their future career progression. As career progression is so important and to encourage the application of best practice, CPD should be a requirement for all professionals to retain their registration status. CPD is, however, not a requirement of many of the current Acts. A culture of Initial Professional Development (IPD) must be developed during the graduate-in-training phase.

Table 25: Details of registration Acts

COUNTRY	ACT NUMBER	ASSESSMENT METHODS				OTHER						
		Detailed experience submission	Interview	Exam	Provision for RPL	Requirement for CPD	Recognition of VAs	Compulsory registration	Registration in public sector compulsory	Council selected or endorsed by Minister or Council (MS/ME/C)	Minister may register individuals	Annual practising certificate
Angola: OEA	Decree No. 39-E/92, 1992	Qual.	-	-	-	-	-	-	-	C	-	-
Botswana: ERB	Eng Reg Act CAP 61:0, 2009 & Act 23/2013	√	-	-	-	√	√	√	√	ME BIE	-	√
Eswatini: AESAP	Act 15/2013	√	√	√	√	√	√	-	-	ME	√	√
Madagascar: OIM	Law 95-024, 1995	√	-	-	√	√	?	-	-	C	-	-
Malawi: BoE	Act 17/1972 Amended Act 5/1988	√	√	√	-	-	-	√	√	MS	-	-
Mauritius: CRPE	RPEC Act 49/1966 Amended 1967	√	√	-	-	-	-	-	√	ME VAs	-	√
Mozambique: OrdEM	Law No. 16/2002	√	√	-	-	-	-	√	√	C	-	-
Namibia: ECN	Act 18/1986 Amended Act 25/1991, GN 22/2004	√	option	-	-	-	-	-	-	MS	-	-
South Africa: ECSA	SACPE, Act 81/1968 ECSA, Act 46/2000	√	√	option	√	√	√	-	In nat. & prov. depts	ME	-	-
Tanzania: ERB	Act 48/1968 Amended Act 15/1997, 24/2007	√	√	√	-	√	√	√	√	MS	√	√
Zambia: EngRB	Act 17/2010	√	-	-	-	√	-	√	√	C	-	√
Zimbabwe: ECZ	Act 3/2008 (Ch 27:22) & Statutory Instrument 153 of 2012	√	-	-	-	-	√	-	Exempt	MS	-	√

ME = Minister Endorses MS = Minister Selects C = Council Selects VAs = with the help of VAs (or BIE)

RECOGNITION OF VOLUNTARY ASSOCIATIONS (VAs)

Some Acts recognise the value of voluntary associations (VAs) and require the registering body to assess the services offered by VAs to ensure that they are up to standard. Registering bodies set criteria for the size and services that voluntary bodies are expected to offer to be recognised as VAs.

In some countries membership of the engineering VA is compulsory and in others recognition of competence is required by the VA before practitioners can be registered by the registering body.

COMPULSORY REGISTRATION

There is disparity in the requirements for compulsory registration and membership of VAs. In Zambia and Tanzania, registration is compulsory, hence large numbers are registered, as shown in Table 24. These institutions keep a close watch on the industry in terms of quality of work and registration of practitioners in all companies and on sites. In other countries, even though registration is compulsory, it is not enforced.

In South Africa, the Act requires practitioners to be registered who are carrying out *'engineering work'*. The definition of engineering work has never been agreed upon, and in 2015, the Competitions Commission ruled that compulsory registration was anti-competitive and was not acceptable. This flies in the face of world best practice and the Constitution, which states that the public has a right to be protected in terms of health and safety.

In Mauritius, only a subset of those carrying out engineering work are required to be registered professionals. The Act states that '*Nothing … shall prevent or deem to prevent … any person from operating, executing, or supervising any works as owner, contractor, superintendent, foreman, inspector or master*', and goes on to exempt '*the work of an employee … of a person registered …, where such work does not include final designs or decisions …*'.

Membership of VAs, as the name suggests, is voluntary in most countries, except Zambia and Zimbabwe. In Zambia membership of the EIZ is compulsory and in Zimbabwe registration with the ECZ is only possible after an applicant has been assessed to be competent and made a Corporate member of the ZIE.

REGISTRATION OF PUBLIC SECTOR EMPLOYEES

Although they are not always defined in the Acts, regulations associated with registration and posts have been developed in most countries. In some countries, such as Malawi, Tanzania and Zambia, public sector engineering officials are expected to be professionally registered, while in Zimbabwe, the law specifically exempts public sector officials from being registered. In South Africa, registration is required for personnel filling technical rather than management posts in provincial and national government. Registration is not specified as a requirement by local government or the utilities.

In those countries where registration in government is compulsory, a problem has arisen in that new graduates cannot be appointed into the structures and trained to grow in the ranks. Where efforts are made to take graduates on for training, they are offered short-term contracts. Thereafter they find themselves unemployed and the departments are without the resources that they have trained. Organograms need to be revisited and must span from junior to senior posts. Registration should only become a requirement above a certain grade.

REGISTRATION OF ACADEMICS

The registration of academics also varies throughout the region. Academics reported one or more of the following differences in their countries:

- It is compulsory for academics to be registered
- It is extremely difficult for academics to register
- Academics are registered as a matter of course
- Registration for academics is not catered for.

To ensure that academics have appropriate qualifications and experience, either in practice, or as researchers, or both, regional criteria need to be decided upon for the registration of academics.

APPOINTMENT OF COUNCILS

With regard to the agreements developed by the IEA, engineering registration boards should be independent of government to ensure impartiality in setting standards, and in decisions relating to accreditation, registration and malpractice. Many Acts have been carefully crafted to ensure that, although the Acts are statutory, members of the councils are selected from the pool of professionals in each country, and are nominated by VAs and the councils, and not government. Although ministers may appoint the councils, they do not involve themselves in the process, but merely rubber stamp the selections made by professionals (denoted as ME in the table for 'Minister Endorsed'). In this way, the IEA has accepted that statutory bodies may serve as accrediting bodies on their behalf.

Some Acts, however, give the minister the power to select and appoint councils (shown as MS in the table for 'Minister Selected'). Such registering bodies would not be able to serve as signatories to the accords or the mobility agreements. It also means that there may be long delays between the end of one council's term, and appointment of the next council, as identifying and appointing council members is not always a priority within the ministry under which the council falls. Consideration needs to be given to peer selection and the wording, '*appointed by the Minister on recommendation of*' should be included in all Acts.

POLITICAL INTERFERENCE

Of concern is the fact that a few Acts empower the minister to overrule the accreditation and registration decisions made by the appropriate committees. Cases have been reported of ministers insisting that an applicant be granted professional registration, even when the committee has determined that the applicant has not achieved the outcomes and level of competence required. This flies in the face of the registration philosophy, which is to protect the public from inadequate designs and solutions, which are usually the hallmark of those with insufficient experience to solve complex engineering problems. A review of these clauses is urgently needed.

ANNUAL RE-REGISTRATION

In some countries, re-registration is stringently administered annually and professionals are given an annual licence to practise. If fees are not paid by the cut-off date, the names of those registered do not appear on the annual register. In others, even if registration fees are not paid, names continue to be published but a series of warnings are issued before the professional is finally struck off the list.

ACCREDITATION OF QUALIFICATIONS

Acts vary in their requirements for registering bodies to perform as the accrediting bodies for tertiary education engineering qualifications, as outlined in Chapter 7.

MALPRACTICE

All Acts assign the responsibility of addressing malpractice to registering bodies. However, in some countries they may only intervene when practitioners who are reported for poor performance are registered professionals. This means that those practicing without registration must be charged through the courts, which is a lengthy process. Until compulsory registration is in place, this will continue to be a problem.

In some countries registering bodies wait for complaints to be formally lodged before investigating malpractice and in others registering bodies have teams of inspectors actively looking for transgressions.

UPDATING OF ACTS

The previous comparisons are based on requirements and activities defined in the various engineering Acts. However, much more detail is contained in by-laws and regulations, which would also be valuable to share with Member States.

Several registering bodies in the region are considering updates to their Act and bylaws to accommodate many of the omissions and shortcomings discussed.

RECOMMENDATIONS

There is a substantial amount of work to do to achieve alignment of professional registration in the region. Until there is uniformity in qualifications and registration requirements, the mobility of engineering resources will be restricted, limiting the potential for local practitioners to contribute towards infrastructure development and industrialisation.

A regional committee/working group

A subcommittee under the TCCA, composed of registering bodies, those aspiring to introduce registration, a representative from the Southern African Federation of Engineering Organisations (SAFEO) and, when required, advisers from the IEA, should be set up to interrogate all Acts and best practice in registration, and to ensure that all adopt one set of outcomes per category and similar assessment processes to achieve a standard on which the region can rely.

Harmonisation of approaches

Issues that will need to be considered are:

- Categories of registration, qualifications required and attributes for professional registration
- Methods of assessment
- Approaches to be adopted for RPL
- Approaches for assessing foreign qualifications
- Appropriate workplace experience and minimum duration before graduates may apply for professional registration
- CPD requirements for retaining registration and initial development expected of graduates
- Recognition, membership and roles of VAs
- Types of engineering work that can only be carried out by registered professionals
- The criteria for registration of academics and public sector engineering practitioners
- Methods of appointing registration councils, assessors and reviewers to ensure impartiality
- Licensing versus registration
- Handling of malpractice
- The development of a SADC Register modelled along the lines of the International Register.

Promoting professional registration

Registering bodies and VAs should work together to promote professional development and registration to ensure a standard of engineering that can be relied upon. In the words of Eng. Martin Manuhwa, when he was president of SAFEO in 2017, *'… there is a need to … mainstream the development of engineering programmes to promote infrastructure development in Africa'* and for all African countries *'… to be signatories of the International Accords, Competency Recognition and Mobility Agreements …'*.

Chapter 10

Tomorrow's leaders

Developing tomorrow's engineering specialists, experts and leaders requires more than university education and graduate training. They must be visionary strategists, able to conceptualise and implement unique solutions to address client and global needs, and must inspire others to be part of the vision and solution. This requires the development of not only graduates but young professionals and those in their mid-careers to grow into leadership roles.

The diagram in Figure 24, which was developed by Engineers New Zealand, shows possible career paths for an engineering practitioner.

CAREER PROGRESSION

The education, early workplace training and registration process have been covered. However, professional registration is only the beginning of an engineering career. After the registration milestone, engineering professionals will continue to build expertise from project to project. Although they are able to operate independently after registration, most professionals will work on complex projects that require considerable teamwork. Team members will debate possible solutions, challenge each other's views, learn from each other, and develop throughout their careers, ultimately becoming the experts who are now in great demand.

As their careers progress, they may elect to become technical specialists, or follow the management route, or a combination of both. As they advance, they will increasingly be given the responsibility of supervising others and checking their work, and later motivating and leading teams, departments or organisations. The progression of roles and responsibilities for a practitioner who remains in the corporate environment is described in more detail in Table 26.

It should be noted that there are many stages in the graduate development process. The speed with which the graduate develops is dictated to some extent by the projects and supervision in place, but largely by the graduate's own initiative and willingness to investigate and research solutions independently and to take on increasing responsibility.

In all cases, to succeed, ongoing development is essential. Development opportunities, however, seemed to be limited in many SADC countries, particularly in ministries.

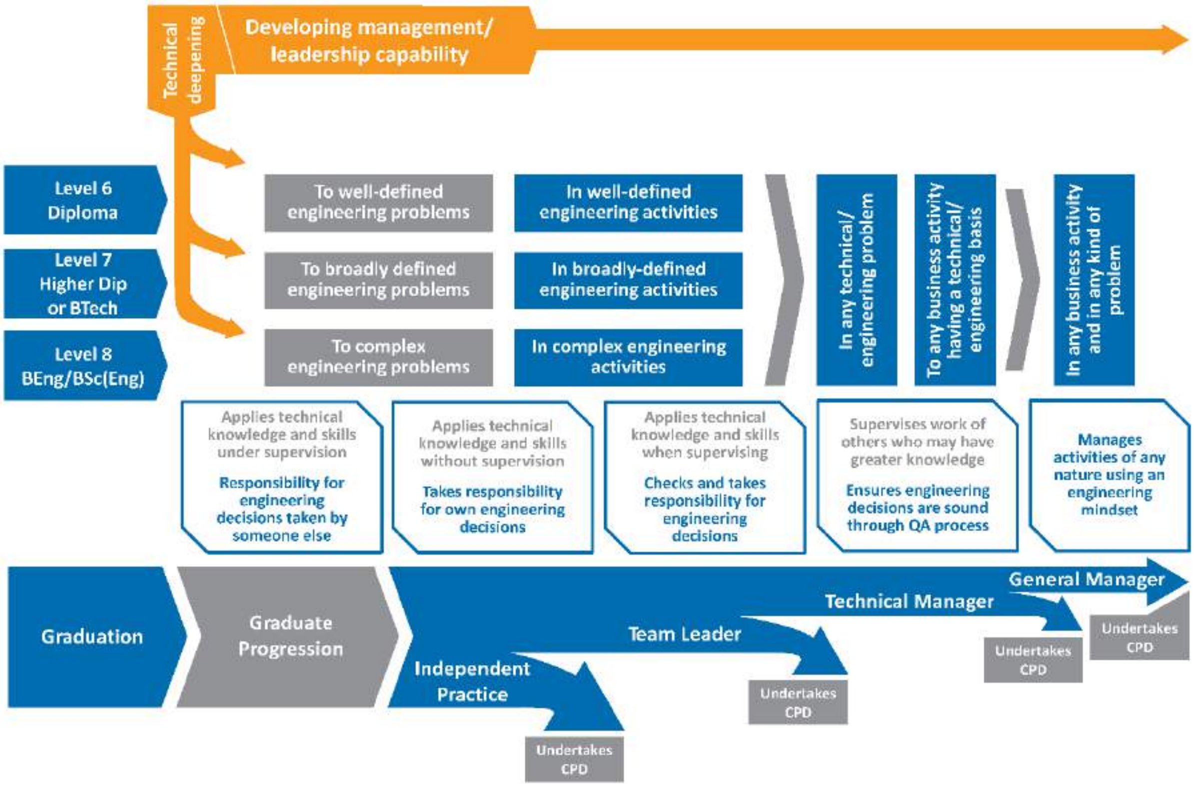


Figure 24: The engineering career model

(Courtesy: Engineers New Zealand)

Table 26: Career progression

Increasing Complexity and Responsibility

STAGES	ACTIVITY
Graduate	▪ Responsible for initial checking of own work on basic engineering activities under close supervision during orientation period
	▪ Responsible for managing and prioritising own work, following standard processes and procedures when working on engineering activities under supervision
	▪ Responsible for parts of, or small projects, processes or systems under limited supervision ▪ Manages and checks own work and that of others, prioritises tasks, organises activities, prepares documentation, and attends internal meetings
	▪ Same as above on larger and more complex engineering activities under minimum supervision
Independent Practice	▪ Responsible for projects, processes or systems mainly without supervision ▪ Manages and checks own work and that of others, advises and coaches when required, prioritises tasks, organises activities, prepares documentation, attends internal meetings and external project meetings or engagements with suppliers or stakeholders
	▪ Responsible for projects, processes or systems of increasing complexity, seeking expert advice when necessary ▪ Schedules resources as required, prioritises tasks, organises activities, prepares documentation, attends meetings as above ▪ Checks own work and that of others, advises, coaches and motivates staff as required
Team Leader	▪ Solely responsible for major, complex projects, processes or systems from inception ▪ Plans, schedules resources as required, prioritises tasks, organises activities, prepares documentation, attends a range of internal and external meetings ▪ Manages staff as above and assumes mentoring role ▪ Becomes involved in corporate planning and performance reviews, setting long-term goals, budgeting, negotiating, reporting etc.
Technical Manager	▪ Senior manager responsible for one or more teams and multiple projects ▪ Oversees the planning, design and implementation of major projects, processes or systems, schedules resources within budgets and timelines, organises activities, attends a range of meetings including national events ▪ Becomes more involved in corporate activities as above, plus recruitment ▪ Takes on corporate roles of motivating for budgets, negotiating with funders, service providers and suppliers, and handling stakeholder and inter-governmental relations
	▪ Part of senior management involved in corporate strategy and setting and managing key performance areas ▪ Oversees the planning, design and implementation of major projects, processes or systems within tight constraints and dealing with stakeholders as above ▪ Responsible for organising activities, attending major national and international events
General Manager	▪ Becomes Technical Director responsible for leading an office, plant, factory or site and making technical and related strategic decisions OR
	▪ Becomes General Manager responsible for making strategic corporate decisions

DEVELOPMENT ACTIVITIES

There are three areas of development that must not be overlooked, namely continuing professional development (CPD), technical and management development.

CPD

CPD applies to all engineering professionals, regardless of the career path they choose as outlined in the previous chapter. Not only does attending CPD events offer formal learning, but networking with others in the industry often offers more insight than the content of the course or workshop itself. Attendance at such events should be supported and budgeted for in all organisations.

CPD activities should not be limited to technical topics. Financial management, advanced use of software and negotiating skills are all important for enhanced performance, among others.

Upskilling of the existing workforce is also critical to cope with change and to adapt to the demands and development of the fourth industrial revolution and advanced technologies.

TECHNICAL DEVELOPMENT

Technical leaders need to be innovators and experts in their field. The SADCQF for Level 8 describes engineers as being able to think critically, conceptualise and develop original solutions. The final two Levels, 9 and 10 on the qualifications framework, require even more of professionals.

- **Level 9:** Demonstrates mastery of theoretically sophisticated subject matter, showing critical awareness of current problems and new insights at the forefront of the discipline area. Shows independence, initiative and originality in complex and unpredictable situations.
- **Level 10:** Makes a substantial and original contribution to knowledge in the field of study through research and scholarship.

Level 9 is clearly the kind of mastery required of a technical leader and relates to the level achieved after completing a Masters' degree. Post-graduate studies, and particularly the research required in a Master's, forces students to work independently and become the critical thinkers. Professionals should be supported to complete Master's degrees, whether part-time or full-time. Where appropriate qualifications are not available locally, study outside the country should be encouraged, linked with contracts for incumbents to return and work for the funding organisation.

In two separate major research exercises carried out in the engineering profession in 2004 and again in 2014, it was found that some 40% of all successful senior engineering personnel in South Africa had a post-graduate qualification of some sort.

Employers should not limit themselves to supporting Master's studies, but should strive to develop expertise and support PhD studies in niche areas, as this will assist corporates to differentiate themselves in the market, and governments to ensure that they are delivering optimum engineering solutions nationally.

Of concern is the limited number of post-graduate courses and engineering research being carried out in the region. From 1994 to 2008 it is reported that South Africa contributed 79% of all SADC scientific publications.

ENGINEERING MANAGEMENT

It has been suggested that to develop managers, three types of knowledge and experience are required. They are:

- **Declarative knowledge:** Knowing 'what', which requires a primary degree in a particular discipline, e.g. engineers completing an engineering degree.
- **Strategic knowledge:** Knowing 'why, where, who and how' in the primary field. This requires experience of at least five to seven years, to develop contextual expertise.
- **Procedural knowledge:** Knowing 'how' in the management field after completing management studies to develop an understanding of management principles on which to build procedural expertise.

Professionals moving into this stream should be encouraged to complete some form of management studies.

LEADERSHIP

Once such individuals have gained experience and have developed expertise in a specific area, society relies on them to lead, drive change and embrace innovation. Recognising this need, the University of the Witwatersrand's Business School has introduced a Master's degree and a post-graduate diploma in the field of Energy Leadership. One of the key aims is to *'… develop a new generation of decisive, effective and solutions-oriented leaders that the sector so badly needs … we now need to develop the leadership skills to manage change and transformation'*.

The Business School is also inviting doctoral candidates to pursue a PhD to develop new research in African energy leadership. Engineers should not just be technocrats, but should be developing throughout their careers to deliver solutions appropriate to the time and need.

The League of European Research Universities (LERU) has also realised the need to address management and leadership development for PhD students so that they can sell their innovative ideas and lead change.

THE DEVELOPMENT HIERARCHY

All too often it is expected that a senior person should train a recent graduate in a short period before retiring, or as part of a short-term training contract. Development is a life-long process and one experience builds on the other.

Declarative and strategic knowledge are critical before moving into either the management role or a technical specialist role. Without a thorough understanding of the environment, more advanced coaching and support will be without context and will not be of much value. The stages of development as described in Table 26 require different levels of coaching and skills transfer. Expecting an international expert to teach a recent graduate the intricacies of his or her specialist area would be premature. The specialist should be coaching the technical manager or technical leader, or both. They in turn should be coaching younger professionals, who, in turn, should be coaching graduates and even supporting students on industrial attachments.

Where there is a skills vacuum, and structures must be set up from scratch, the duration of contracts for senior personnel brought in to set up structures, systems and procedures cannot be short term. Staff of different levels of seniority are required, and a culture of skills transfer must be developed. Only when the senior personnel have developed the level of specialist skills required will it be practical to withdraw support.

Of concern in the region appears to be the inability to develop bankable projects. This requires good project preparation where credible risks and potential returns are determined and presented. Master plans need to be in place but, as outlined in Table 26 the ability to plan takes years of experience and cannot be left to junior staff. This must also be part of the skills transfer process when capacitating new structures.

TIMEFRAMES

There is much debate about the pace at which people develop, and there is an ongoing demand to fast-track very junior personnel into senior positions.

Malcolm Gladwell (Canadian journalist and public speaker) is famous for suggesting that the most successful people of the world, including sportsmen and -women, business people and scientists, have not achieved success through natural aptitude alone, but through hours of hard work, such that a minimum of 10 000 hours of application are required to become an expert. The progression of experience and developing expertise shown in Table 26 is a long process, given the complexity and breadth of engineering work.

The temptation to fast-track skills development has resulted in steps being skipped, leaving many young or inexperienced managers floundering. Although fast-tracking may fill senior posts, it will achieve little in terms of building capacity, and in the long run will disadvantage those who have been fast-tracked, because eventually their level of development will be inadequate for further promotion.

Those who are promoted to a level beyond their ability will either make the wrong decisions or will not be confident to make any decisions and will hold up development. They will also not be able to pass on adequate expertise to those who follow.

To illustrate, the fast or express train runs from one major centre to another, without stopping to pick up passengers or goods along the way. Young people today are expected to make it from graduation to senior positions at break-neck speed and are not given adequate opportunity to gain experience along the way. The slow or milk train, on the other hand, stops at every siding and waits for long periods for the fast trains to pass. Care must, however, be taken to ensure that young practitioners are not side-lined on menial tasks or assigned several repeat experiences.

Mainline trains, however, take a little longer than express trains because they stop at the major centres to pick up passengers and valuable commodities. Engineering graduates need to be ‘mainlined’ or ‘right tracked’ and supported from graduation to being tomorrow’s leaders.

RECOMMENDATIONS

Essentially, all employers, whether in the public or private sector, need to recognise that all staff require development throughout their careers.

- **CPD:** Staff should be encouraged and supported to participate in CPD activities, including courses, workshops, conferences, online learning, self-study, etc.
- **Post-graduate studies:** Provide bursaries for post-graduate studies and link graduates to practising specialists to assist with practical application and the development of expertise.
- **Developing managers and leaders:** Employers should continue investing in graduates after professional registration to grow management and leadership capabilities.
- **Understudies:** Mid-career specialists and managers must be assigned to foreign experts to be coached and ultimately to be able to fulfil the role currently provided by expatriates.

Local specialists and strategic leadership are essential to develop appropriate local solutions to complex engineering problems.

Chapter 11

The public sector

Although the region is investing in educating young people with a view to expanding the engineering skills base, it is not developing mid-career practitioners or valuing, using or retaining those with experience. Furthermore, contract conditions often preclude local skills development.

ENGINEERING PROFESSIONALS

In the public sector it was found that the number of engineering staff has reduced over the years, in many instances as a result of short-term saving measures or transformation targets. Years of experience have been lost due to these policies. A lack of skilled personnel results in many unwelcome consequences:

- Long-term planning does not take place.
- Projects are not prioritised and planned for, or uncoordinated development takes place.
- Capital, operating and maintenance budgets are not prepared, or inadequate estimates are made by non-technical managers.
- Decisions are not made, or the wrong decisions are made in terms of projects, appointing service providers and purchasing materials, machinery and equipment.
- Service providers are not adequately managed, and poor quality and overclaims become the norm.
- Operations are not managed, which can result in wide-ranging disruptions, delays or unsatisfactory conditions, as in the case of refuse not being collected.
- Maintenance does not take place, resulting in the reduction of the useful life of assets worth millions, and in some cases billions, of dollars.
- Junior staff are not supervised and developed.

Professionals have much to offer their organisations. As they develop, they are able to take on strategic and leadership roles as shown in Figure 24. However, to attract and retain professionals, the environment must be supportive. This requires an adequate engineering team, systems, processes and acceptable working conditions to be in place. Many challenges were identified in the public sector.

INVESTING IN ENGINEERING STAFF

Throughout the region, there was the mistaken belief that engineers are expensive, and due to budget constraints, the number of engineers in government or local government should be reduced. This is the logic of those who do not understand engineering. The public sector outsources much of its work to private sector service providers. Without experienced engineering personnel defining the scopes of work and ensuring that what is being offered matches the requirements, millions of dollars can be wasted on the development of inadequate solutions, which do not satisfy the needs in the long term.

Furthermore, without experienced engineering personnel overseeing the development of projects or the installation and commissioning of equipment, the final solutions could be far from satisfactory, which may be costly to rectify once projects have been signed off. As discussed above, if maintenance is not managed, the costs upgrades when the infrastructure has failed could be prohibitive.

Given that engineering salaries are a small percentage of the total costs of engineering assets, the ‘cost saving’ associated with reducing the number of engineering staff members per department amounts to nothing more than being ‘penny wise, pound foolish’ as it results in premature infrastructure failure and substantial increases in long-term repair and upgrade costs.

Organograms and competence profiles

When organisations are not functioning effectively, there is a temptation to restructure. In many public sector structures, the solution is simply to ensure that technical posts are filled appropriately qualified and experienced technical personnel. Thus the solution is to rebuild and not to restructure.

Organograms with all levels of staff need to be developed to allow young people to grow through the ranks and to rebuild institutional knowledge. In countries where professional registration is a requirement for appointment, graduates are excluded because they are not professionally registered. Registration should only be a requirement above a certain level or grade.

It was found that many technical posts in the public sector were vacant or were filled by non-technical personnel. All too often cadre deployment or nepotism was the determinant in who should be employed, rather than selecting an appropriately qualified and experienced person.

Competency profiles must be developed and staff must be appointed who have the requisite qualifications and experience, particularly at senior levels. Senior staff must also be given authority to make decisions. This will ensure that there is strategic capacity to plan and implement appropriate solutions.

Table 27: Challenges facing engineering practitioners in the public sector

COUNTRY	EMPLOYMENT OF ENGINEERING PRACTITIONERS IN THE PUBLIC SECTOR
Angola	There are still engineering skills in the public sector, but salaries are said to be lower than in the private sector and attract staff away from ministries and utilities.
Botswana	Salaries are lower in the public sector and funds are not available for CPD. Career progression is a problem in some structures, as staff are not being trained to take over from experienced staff due to retire in the next few years.
DRC	With limited budgets in infrastructure departments, there are few opportunities for development or maintenance. Although posts are not all filled, in some instances, staff complain of not having any meaningful work to do.
Eswatini	Salaries are low, making it difficult to attract high-calibre staff. Junior staff may commence their careers in the public sector, but leave when they have gained experience.
Lesotho	Salaries are reported to be low and positions are not filled when people leave. The value of technical staff has not been appreciated and their recommendations on suitable appointments are often overlooked.
Madagascar	There has been a moratorium on employing staff in the public sector for many years, hence the numbers have reduced over time. Succession plans do not make provision to replace those who are retiring. There are few, if any, specialists in the various structures.
Malawi	The vacancy rate in the public sector is extremely high, reaching 40% in some departments. The very low salaries offered in the sector make it difficult to attract staff.
Mauritius	Local government and ministries generally have limited engineering staff, while posts in the utilities are largely filled. Government salaries are said to be much lower than in the utilities, making it difficult to attract and retain staff in government.
Mozambique	Some Ministries report having adequate engineering staff, while in others there are shortages, particularly of specialists, and posts are not filled when existing staff leave. Salaries are said to be low making it difficult to attract experienced staff when posts are advertised, and limited graduate training takes place.
Namibia	Experienced professional engineers have been replaced by junior technicians, leaving no capacity for coaching and mentoring. With limited experience, they are unable to motivate for suitable budgets, which limits development opportunities and maintenance.
Seychelles	There has been a moratorium on employing staff in the public sector, hence the numbers have reduced over time. Succession plans do not make provision to replace those who are retiring.
South Africa	The number of engineering practitioners has dropped in many government departments, due to budget constraints, and posts are frozen as staff leave. Experienced professional engineers have been replaced with junior engineering technicians. The lack of authority afforded to engineering professionals in terms of leadership and decision-making does not attract experienced engineers into the sector.
Tanzania	There has been a moratorium on employing staff in the public sector, hence the numbers have reduced over time. Succession plans do not make provision to replace those who are retiring.
Zambia	Only a few departments reported vacancies, and practitioners generally valued posts in the public sector as they offered job security and in many cases the opportunity for further study.
Zimbabwe	Salaries are extremely low and as engineering staff have left, they have not been replaced. Generally, only older staff still remain. Succession plans do not make provision to replace those who are retiring.

Tanzania has embraced this philosophy from cabinet level down and has appointed engineers as ministers and principal secretaries in engineering ministries and departments, such as roads and transport, water, public works, etc.

Engineers were also found as principal secretaries or directors general in engineering ministries in other countries, but these were the exception rather than the norm. Without leaders who understand engineering imperatives, the range of challenges, as listed above, will persist.

Salaries

Salaries were found to be a challenge in many countries, with chief directors and even more senior levels earning only US$600 per month. Few senior engineers remain, which is concerning given the value of the infrastructure under the control of each department. Substantial salary increases or scarce skills allowances need be considered to attract and retain engineering professionals. Scarce skills allowances are, however, not favoured, as pension cover, disability allowances and other benefits were not increased in line with the increase in earnings. Total package increases should be considered.

Professional registration and CPD

Many employees from both the public and private sectors complained of the lack of recognition of the importance of professional registration and belonging to professional engineering institutions, or the lack of support or opportunities for CPD. Some reported having to take leave to attend courses.

PROFESSIONAL JUDGEMENT AND AUTHORITY

Engineering professionals are trained to investigate and solve problems and use their engineering judgement to make decisions. Sadly, in many situations in the public sector, the authority to make decisions has been taken away from engineering professionals, to the detriment of service delivery.

Technical decision-making

It is recognised that engineers have a key role to play in conceptualising, planning, prioritising, designing and delivering solutions. However, in the public sector, their recommendations are often ignored or their decisions are overruled.

All too often, grand schemes are agreed upon which are inappropriate. For instance, in a small rural community the idea of a US$20 000 wastewater treatment plant was 'sold' to the municipality, when a waste stabilisation pond could have been constructed at a fraction of the price, which needs little or no maintenance.

Decisions relating to engineering solutions should rest with senior engineering professionals.

Financial decision-making

All too often technical departments are assigned a budget based on the prior year's budget without any consultation. Determining the size of budget required for infrastructure should be the function of technical personnel, considering development as well as operations and maintenance requirements.

There is a need to increase tariffs for services in many countries and to enforce payment by those who can afford to pay, but this is not a popular choice. The AfDB advises that tax revenue collection in Africa is below the threshold of 25% of GDP considered necessary to scale-up infrastructure spending.

Until adequate funds are available for infrastructure, the current cycle of no growth available to fund development will continue. Demand management methods to reduce consumption and losses must be considered, including the use of prepayment meters, repairing or replacing of pipes and cables, etc.

Supply chain

Appointing competent service providers and purchasing appropriate materials is critical for the success of projects, operations and maintenance. All too often these decisions are made by supply chain practitioners, politicians or other non-technical people, but engineering professionals are still responsible for the end result.

Human Resources (HR)

The Human Resources (HR) function has been removed from many technical departments. As a result, new employees are at times not selected by those who will be employing or managing them. This disconnect between the employer and those handling the process results in inappropriately qualified or inexperienced staff being appointed in many cases. It is essential that the screening, selection and appointment process reverts to technical departments and HR only offers the support of advertising, setting up interviews and finalising the contracts. Any interview panel should include professionally registered supervisor(s) and peer(s), where relevant, relating to the position.

Authority

Support departments, although intended to support line departments, have usurped the authority and undermined the processes which are the domain of technical departments. Professionals in any discipline are specifically trained to investigate and solve problems, and to use their professional judgement to deliver solutions. Working in the public sector is particularly frustrating for professionals whose highly developed ability to make professional judgement calls are overridden by support personnel following guidelines that are often not relevant to the issue at hand.

Professionals are accountable for the services they deliver but are often not responsible for the decisions made on their behalf based on inappropriate structures, systems or guidelines. To create an enabling environment for technical professionals, it will be necessary to wrest authority away from support functions and return it to the leaders of line functions.

REGISTRATION OF PROFESSIONALS

Without a measure to ensure the competence of engineering professionals, there is no way of ensuring that those appointed in posts to plan, design or oversee construction or implementation are capable of the task at hand. Senior engineering personnel in government should be professionally registered and should be responsible for developing young professionals in their structures.

DEVELOPING LOCAL CAPACITY

The intention of this research project was to determine the number of engineering professionals in each country, the future demand and supply, and to suggest interventions required to address gaps and grow local capacity and job creation opportunities.

However, as countries are increasingly employing international consultants for the design phase, international contractors for construction, or encouraging international manufacturers to set up local plants or supply, operate and maintain equipment, as part of investment agreements, the opportunities to develop local skills and create local employment appear to be decreasing. This undermines the very spirit on which Agenda 2063 and industrialisation is based. Furthermore, where local appointments are made, they are often not based on technical merit or include skills development requirements. Policies and approaches concerning the following need to be revisited:

- Classification and use of service providers and their conditions of contract
- Adopting local standards and approving solutions locally
- Ensuring localisation as part of investment.

CLASSIFICATION OF SERVICE PROVIDERS

Without a measure for ensuring that service providers have adequate expertise, capital and equipment, contracts have little chance of succeeding if simply awarded to the lowest bidder. As discussed under *Construction* in Chapter 6, the level of sophistication of service providers required per contract will vary according to the complexity and size of the project. Service providers should at least be categorised according to the following:

- The availability of engineering and built environment professionals
- The type and size of machinery and equipment owned
- Working capital available
- Access to finance
- Track record.

Based on these and other appropriate parameters, a limit should be placed on the size and type of project each contractor may be appointed to carry out.

Construction councils in several countries do assess some, if not all, of these parameters. In some countries, foreign companies are precluded from tendering on small projects to protect the many small local contractors and ensure local job creation.

Recognising the need for regional integration and a multi-lateral trading system, the SADC Trade Negotiating Forum (TNF) was set up to negotiate the progressive removal of barriers to trade in construction services and the energy sector within the SADC region. The Forum is composed of officials from ministries associated with construction and energy, and many representatives from construction councils. Member States are expected to make offers in areas of trade that they are prepared to relax. The Forum has been exploring the possibility of relaxing the various conditions set for foreign contractors and consultants to accommodate the mobility of SADC companies. In the absence of agreed standards, this is proving difficult to achieve.

Given the need to create job opportunities and grow local skills, liberalisation in the lower levels could impact negatively on each country's growth, job creation and skills development drives. The following should be considered:

- Develop standardised categorisation criteria for the region, negotiating with contracting companies to ensure that the criteria are practical, rather than imposing unrealistic restrictions. The US$ value thresholds may be different per country based on costs in each country.
- Determine the category below which contracts should be reserved for local contractors.
- Determine the categories for which SADC contractors may be appointed.
- Determine the category above which international contractors may be appointed – this would be higher than for SADC contractors.
- Adopt standardised conditions of contract where practical.
- Set requirements for using and developing local skills.
- Ensure that there are requirements for using local materials, machinery and equipment where available.

The concept and aim of industrialisation is to accelerate growth, create employment and improve living conditions, but all too often when contracts are awarded to foreign companies, foreign skills, material, machinery and equipment are used, limiting local opportunities. The use or importation of foreign equipment is possibly only necessary in the case of specialised mining and manufacturing equipment.

Construction has long been recognised for its job creation potential, and presents significant opportunities to develop engineering graduates, apprentices, small contractors, subcontractors and suppliers.

Furthermore, large and mega projects are the most important way of developing high-level skills and expertise. The approaches outlined in the

Angolanisation and Zambianisation policies, which require understudies to be assigned to foreign experts, must be adopted and enforced. However, as discussed in Chapter 10, staff with experience should be assigned to experts to take the next step in their technical development.

In countries where local development is included in the conditions of contract, these conditions are frequently not enforced. Regional resolve to grow local skills and opportunities is critical.

ADOPTING LOCAL STANDARDS AND APPROVING SOLUTIONS LOCALLY

When international service providers are used, design solutions cannot be checked at times due to language barriers or different approaches and terminology. Furthermore, the lack of knowledge of local conditions often results in inappropriate designs.

Although the world is now considered to be a global village, local conditions, needs, customs, styles and habits need to be considered when developing solutions. Variables such as the weather, the orientation of buildings relative to the position of the sun in the southern hemisphere, geotechnical conditions, religious beliefs, local lifestyle, customs and indigenous systems need to be considered. Many of these factors are not considered or are ignored, at great cost to each country, when designs are concluded without consultation and approval by local engineering and built environment professionals.

The failure of the high-rise housing development in Luanda, which did not consider local needs or style of living, is well documented. Selecting inappropriate material has resulted in the failure of many roads. The inappropriate orientation of buildings has caused much discomfort due to excessive exposure to the summer sun. The use of international, rather than local, codes has resulted in the failure of stormwater systems, as the size of 20- and 50-year floods was underestimated. These and many more examples have been challenged by local engineers, but have been ignored, or overridden by the powers that be.

A policy should be put in place, and adopted throughout the region, requiring that all designs carried out internationally be checked and approved by local engineers together with the client body. This would ensure that all design calculations, drawings, operating manuals and associated documentation are made available in the local language, which is not happening at present. Local teams would then be able to operate and maintain the infrastructure rather than relying on only those who can read the documentation.

The use of local conditions of contract should also be encouraged to incorporate local practice and support the use of local supervision.

Developing local codes and standards

Some countries do not have a full suite of locally researched and developed engineering design codes and standards. As described above, using inappropriate values for various controlling parameters can result in unsuitable solutions being developed. Support is needed to research local parameters and develop new codes, or to adapt codes from other countries to match local conditions.

Unbundling of projects

Many major projects are awarded on turnkey contracts. This means that the company that is awarded the contract is responsible for both design and construction or implementation. There is thus little or no oversight at the delivery stage. Traditionally, when separate design and construction contracts were awarded, the consulting engineer who designed the project would oversee construction and ensure that the work was carried out in accordance with the design and local specifications. Consideration needs to be given to unbundling of projects or at least providing local professionals, with authority, appointed by the client, to oversee the design and delivery process.

LOCALISATION

The preceding discussions have largely covered skills development associated with public sector infrastructure. Where countries are looking to investors to develop the local manufacturing sector, it is also important that funds coming into the country are spent on developing local skills and capacity. All too often investors supply their own skills, machinery and equipment to develop a local resource. While this may be necessary at the outset, the manufacture of local components and the employment of locals and skills transfer should be factored into all agreements.

In many cases, subsidiaries of international companies only employ elementary skills locally but provide high-level skills from their headquarters. While it is understood that control is required, there is no reason why local professionals cannot be developed to become part of the international executive team. Skills development at all levels should form part of offset agreements.

Many countries look at investments on a case-by-case basis to identify localisation opportunities. Regional knowledge-sharing in this regard and implementing more robust policies should be considered through the Industrial Development Forum. These should include penalties where investors have committed to use local materials, develop component manufacturing plants, support and train emerging manufacturers, but have ignored their obligations once set up in the country.

This project would not have adequately served the region if policies do not emerge to protect and develop opportunities for local engineering skills and job creation. Institutional commitment will, however, be necessary to ensure that such localisation policies are enforced.

INVESTMENT

Adequate investment in the planning, development, operations and maintenance of infrastructure, products, systems and/or processes is essential for success. Key elements to consider are:

- Investing in infrastructure
- Investing in maintenance
- Investing in systems
- Investing in research and new technologies
- Sourcing funding that is best value for money
- Investing in agricultural solutions
- Developing rural solutions
- Investing in reliable data.

INVESTING IN INFRASTRUCTURE

The most elaborate industrialisation plans will not make a substantial impact on growth without developing economic infrastructure. In most countries the inability to transport agricultural products or mining output to markets was noted as a major limitation. Furthermore, the lack of energy and clean water is an impediment to existing organisations, let alone the need to develop new market niches. Before the number of graduates is increased, commitment to development and investing in infrastructure is key. Once projects are underway, they offer an ideal training ground for new graduates.

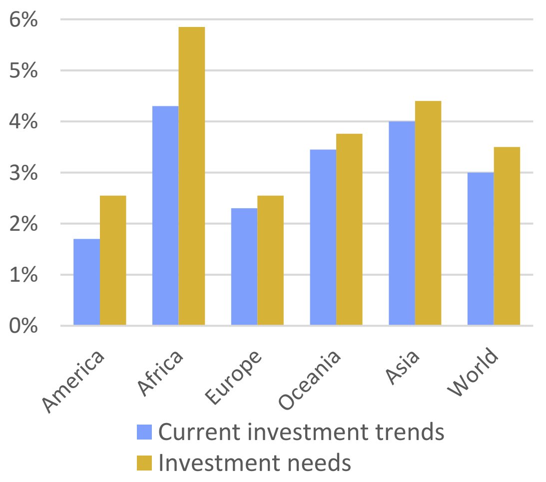


Figure 25: Infrastructure financing gaps as a share of GDP in selected regions, 2016–2040
(Africa Economic Outlook 2018, AfDB)

The *Africa Economic Outlook 2018* reports that the world needs to invest an average of US$3.3 trillion per year to support currently expected rates of growth. However, there is a large gap, when considered as a share of the GDP, the largest being in Africa, as shown in Figure 25.

INVESTING IN MAINTENANCE

Once there has been investment in infrastructure, there is a need for ongoing maintenance. The range of maintenance activities includes preventative maintenance, planned maintenance and routine maintenance, all of which can dramatically extend the life of infrastructure. If these are not in place and aggressively managed, infrastructure can fail years before the end of the design life at substantial cost to the country.

When considering roads for instance, if they are only maintained for the first time after 10 years rather than after 6 to 7 years, the cost will be six times greater, and if left for 15 years, the damage and upgrade needs would cost about 18 times more than if maintenance had been carried out every 5 to 7 years. Countries cannot afford maintenance once roads or any other infrastructure requires rehabilitation. If attention is paid from the outset, the cost of maintenance is relatively low.

In the words of Saied Solomons, President of the Southern African Road Federation, '*preserving Africa's road assets at times gets overshadowed by what's new but is the backbone to infrastructure provision. For politicians, preservation is not as attractive as a new piece of infrastructure, but it is ignored at its peril*'.

INVESTING IN SYSTEMS

Many previously functional systems have not been kept up to date, making management of infrastructure difficult. Systems need to be reinstated and updated to improve the efficiency of technical departments, particularly in the absence of a sufficient number of skilled staff.

Standard operating procedures have disappeared over time, and there are limited guidelines for new appointees to follow. Preparing budgets, dealing with public complaints, and planning and reacting to operations and maintenance needs are the first systems to suffer.

INVESTING IN RESEARCH AND NEW TECHNOLOGIES

Clearly from the discussions thus far, the SADC region is unique and is rich in resources – from minerals and gems to fertile agricultural lands and a long coastline, among other things. Opportunities abound to harness these resources and create new industries along with millions of new jobs, but such solutions will not emerge without research, development and understanding market needs and trends.

The region is also faced with many challenges – global warming, climate change and some countries are water stressed. Solutions to address these challenges are also needed. The region cannot wait for solutions to appear, they must be researched and developed locally to ensure that they address the local needs.

Furthermore, much equipment is out of date and inefficient in terms of energy and fuel consumption and the like, and should be replaced to reduce operating costs. In delaying the investment into new technologies and solutions, countries are wasting millions of dollars on operating costs.

SOURCING FUNDING THAT IS BEST VALUE FOR MONEY

In times past, funding was made available with various terms and conditions to ensure that sustainable solutions were developed, and funds were put aside for maintenance. More recently, more expensive funding has been accessed with no strings attached other than repaying the funds over many years in either cash or goods. These funds have, however, often been supplied along with foreign labour, materials and equipment, offering little or no economic benefit to the receiving country, or include conditions of transfer of the ownership of the asset or associated commodities to the funder if countries delay repayments or default. This has negatively impacted many countries.

Taking this easier but unsustainable option has invariably been the decision of high-ranking officials or politicians who have benefited personally from the funds. Corruption has taken its toll on the region.

Regional policies need to be developed with regard to the type of funding that should be harnessed, and the terms and conditions that should be set for both funders and recipients.

INVESTING IN AGRICULTURAL SOLUTIONS

Of concern has been the limited progress evident in increasing agricultural output and strengthening subsistence farmers. As agriculture is the primary employer in many countries and subsistence farmers produce a substantial portion of the food, urgent attention needs to be given to helping farmers to improve their productivity, develop and market cash crops, and get their goods to the intended destination efficiently. Modernisation, mechanisation (even handheld), irrigation, improved inputs and agro-processing opportunities need to be considered and complete value chains need to be developed. The potential is there to increase productivity, increase exports, reduce imports and create wealth.

The SADC Food, Agriculture and Natural Resources Directorate (FANR) should engage with the Pan African Society of Agricultural Engineers, a network of agricultural engineering professionals in academia, research, industry and policy, for their ideas on possible engineering solutions in agriculture, food security and related industries. The Mauritian model of making equipment available to smallholders should also be considered.

The essential message of the *2017 State of Food and Agriculture* report by the FAO is that the key to achieving the 2030 Agenda for Sustainable Development is in transforming rural communities and promoting agriculture. The FAO recognises the large growing rural population and the need to make small units productive. Strong local organisations need to be formed representing the rights of farmers able to enter the agro-processing value chains, gain access to markets and negotiate with traders, food processors and retailers.

It was found that in many countries investment in and support for agricultural engineers, technicians, agronomists and extension services had reduced, leaving farmers to follow traditional, inefficient methods. The ratio of farmers to agricultural engineers and agronomists made it impossible to drive large-scale changes. This urgently needs to change.

Another problem that was identified is the approach to training agricultural practitioners. Limited hands-on training takes place during their academic studies, and since they have only theory and limited experience or practical advice to share, smallholders

Figure 26: Maasai warriors jump at sunrise near their village
(Photographer: John Kerrod Wells)

place no confidence in the solutions that they suggest. Disillusioned with their first attempts to contribute, many leave the sector. It would seem that substantial internships on farms should become part of these qualifications, similar to the structure of medical qualifications, or rigorous structured graduate training must be put in place.

Agricultural engineering and extension services hold the key to developing opportunities for rural communities to earn a decent living and become the source of each nation's food.

DEVELOPING RURAL SOLUTIONS

Much has been written about the need for decent work opportunities. Indeed, SDG 8 calls for '*Decent work and economic growth*'. The question must, however, be asked: what is decent work?

Does the proud Maasai Warrior herding and protecting his livestock, raising his mischievous little sons on the land and sharing indigenous knowledge with them, not enjoy a decent day's work?

Many rural communities would consider that their daily working experiences are satisfying and more than decent. What is not decent is their living conditions – they are often appalling. The lack of electricity, long walks to collect water (and the increased risk of being attacked or raped), the hard work of collecting firewood for cooking and heating and, in many places, the lack of protection from the elements make for tough living conditions. Furthermore, there is often limited access to education and health care facilities.

Moving to the cities and following a lifestyle associated with the high GDP per capita suggested by Agenda 2063 is an alternative that is far from being able to offer decent work or living conditions for all in the foreseeable future. The nightmare of slum dwelling is well documented and evident throughout the region. With the large, increasing under-15 populations and growing automation in the formal sector, there is limited prospect for large numbers to be absorbed into formal employment in the cities.

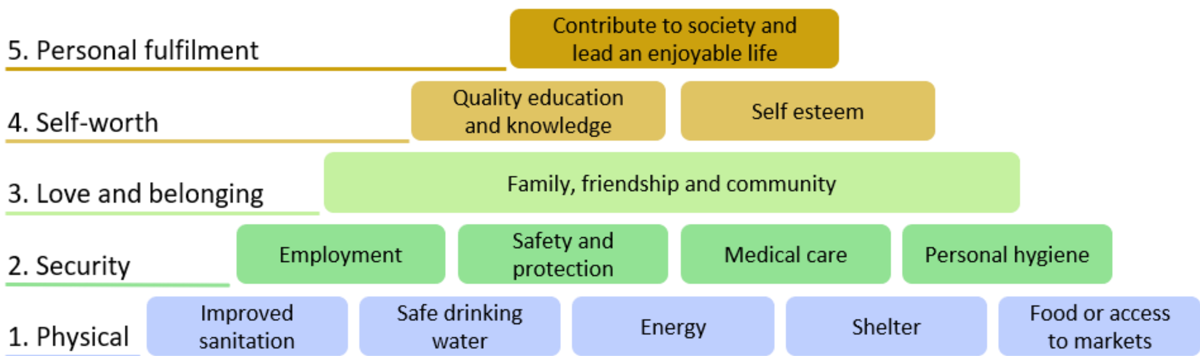


Figure 27: Infrastructure requirements for rural communities considering Maslow's Hierarchy of Needs

As discussed in Chapter 1, historically, transport and associated infrastructure development was linked to the exploitation of resources, whether in mining areas, commercial centres or linking to ports. Limited infrastructure has been extended to rural communities.

Considering Maslow's Hierarchy of Needs applied to rural communities, factors such as employment, family, friends, community, indigenous knowledge and fulfilment in contributing to society are in place. However, water services, energy, markets, community centres, health and education facilities need to be made available to support and grow communities, and to encourage de-urbanisation. Rather than cost nations, such developments will increase food production, reduce imports, increase income, and address the missing elements in Maslow's Hierarchy of Needs. They will also reduce the costs of having to support large numbers of poor people struggling to survive.

INVESTING IN RELIABLE DATA

Labour force surveys and availability of data

This project has been extremely difficult due to the lack of data. As discussed in Chapter 5, only the Seychelles and South Africa could provide data down to occupation level and even these figures could not be used without some adjustment based on understanding qualification levels and sectors. Labour force surveys are therefore nothing more than overall employment status quo reports and are of little or no value for skills planning. The region needs to consider different methods of gathering the detail of employment data.

Labour force surveys should be enhanced by increasing the sample size and setting up a more robust method to determine occupations.

Alternatively, as part of annual personnel tax returns, more information about occupations should be gathered from each taxpayer and employers should be asked about skills shortages and needs when completing the annual company returns. This will not cover the informal sector but will offer a clearer picture of the number and type of skills employed in the formal sector and allow better skills planning.

Higher education data

Higher education data also proved extremely difficult to collect, for two reasons: the lack of records and the inconsistency in qualification naming and levels.

Few institutions could extract the data requested from a system but needed to go through their annual records to provide the data. Others were not that fortunate and needed to read through graduation programmes to count how many of each discipline graduated each year.

South Africa and Mozambique had a central database from which the information could be extracted. Angola and Madagascar have started collecting data centrally since about 2013 and were able make annual reports available down to discipline level. Other education departments could offer total numbers graduating per year, but not down to discipline and gender level.

Consideration should be given to developing a central system into which all countries can report. This does not mean that every country needs to use an identical system, but interfaces will need to be developed that will allow the required data from national systems to be uploaded into a regional system.

For mappings to be possible it will be necessary to have all National Qualification Frameworks aligned and the different types of qualification categorised.

Support of professional bodies

As discussed in Chapter 9, registration bodies are key structures to drive the development of engineering competence. Consideration should be given to designing comprehensive data structures which can be a resource not only for managing these institutions, but also for feeding into national skills planning initiatives. Many datasets received contained only the contact details of members, but they should be expanded to include disciplines, specialisation, region, age, gender and nationality, among the many parameters that need to be managed. Reliable data could also be of benefit to immigration authorities for approving work permits for those with scarce skills.

RECOMMENDATIONS

A strong public sector is critical to ensure that infrastructure is planned and developed, and that conducive policies are in place to support the development of the agricultural, construction, manufacturing and mining sectors. Substantial changes in approach to training and harnessing professionals, appointing service providers and investing in development are required.

Engineering professionals

Public sector structures need to consider:

- **Technical staff:** Revisit organograms and rebuild structures to allow for career progression.
  - Reprioritise budgets to fill vacant posts, ensure that salaries are competitive and develop succession plans from junior levels to make the public sector an employer of choice.
- **Authority:** Give authority to engineering personnel for:
  - Long-term planning, prioritisation of projects and decision-making in consultation with stakeholders.
  - Appointment of technical staff.
  - Budgeting for the development, operations and maintenance of infrastructure.
  - Supply chain decisions with respect to both service providers selected and products purchased.
- **Training and development:** Commit to staff training and development at all levels.
  - Ensure that every technical structure sets up an internal graduate training and development programme, with the required support to ensure its sustainability.
  - Support CPD and the development of young professionals, technical specialists, managers and leaders.
- **Resources:** Ensure that departments have adequate systems, software and equipment.
- **Systems and procedures:** Redevelop systems and implement standard operating procedures.

Registration of service providers

Form a subcommittee under the TNF to review and harmonise all construction council Acts and contracts and encourage others who do not have a system in place to follow suit. Items to be considered include:

- **Grade:** Grade of contractor based on working capital, machinery and equipment, premises and skills sets (such as engineers, architects, tradespersons, etc.).
- **Categories:** Categories of contractors relating to the type of work they may take on.
- **Conditions:** Period of registration, licensing and insurance requirements.
- **Local support:** The levels below which foreign participation should be excluded and, for larger contracts, the requirements for foreign contractors to use local labour, subcontractors, materials and machinery, and to form joint ventures with local companies.
- **Training and development:** Training criteria relating to skills, small contractors, subcontractors and, where appropriate, communities.
- **Suitability of solutions:** A mechanism for assessing and approving proposed solutions, ensuring that they address local needs and customs and that designs comply with national codes and standards.
- **Handover:** The documentation required at the time of handover.
- **Quality assurance:** Mechanisms for monitoring progress and imposing penalties for poor performance.

Localisation

The Industrial Development Forum to share experiences on setting up offset agreements relating to local development with foreign investors. Agreements should include not only the use of local labour, plant, equipment and developing local manufacturers but should include the training of engineering professionals.

Investment

Reprioritising budgets, accessing funds with the most favourable terms and collecting outstanding funds in each country will be essential to ensure that infrastructure development takes place in a sustainable manner. Consideration must be given to the following:

- **Economic infrastructure:** Investing in the development of economic infrastructure such as electricity, roads, rail, ports and airports, and addressing the supply of water services.
- **Maintenance:** Investing in maintenance to preserve the integrity of new infrastructure and to prevent further deterioration of existing infrastructure.
- **Tariffs and payment:** Reviewing and increasing tariffs where appropriate, enhancing domestic revenue collection and demand management to fund development.
- **Cost-effective solutions:** Developing cost-effective and bankable projects and identifying and agreeing on funding options that offer the most favourable terms, at the same time avoiding risks that could be detrimental to the country in case of delayed payment or default.
- **Research and new technologies:** Investing in research and new technologies to address local needs.
- **Agricultural and rural development:** Investing in agricultural development, particularly support of smallholders, and developing rural communities and economies.
- **Data availability:** Investing in more robust labour force data acquisition and management models, in the collection and management of tertiary education data, and in engineering registration data.

Chapter 12

Numbers and Needs

Many research projects, papers and forecasts have suggested the need for many more engineers in Africa, with one paper suggesting that Africa needs 4.5 million engineers. This is premised on the number of engineers per hundred thousand population in OECD countries. But does this need exist?

THE ROLES THAT ENGINEERING PRACTITIONERS PLAY

To answer the question, one must consider the roles that engineers play. They design, develop, operate and maintain infrastructure; conceptualise, build and operate manufacturing and processing plants and mines; and contribute to agricultural production through the use of technology. This means that infrastructure must be in place and funds must be available for ongoing development, operations and maintenance, and that manufacturing must be of the complexity that requires engineering skills. The level of service with regard to infrastructure is also a deciding factor on the type of engineering skills required. Considering each in turn will offer a better picture of the numbers required.

INFRASTRUCTURE

It is important to consider the level of service and extent of infrastructure per country.

Levels of service

The remoteness of many communities means that the delivery of piped water, waterborne sanitation and electricity from the grid is unaffordable and impractical in terms of capital costs and ongoing operations and maintenance. As a result, localised solutions have been developed, including yard tanks, ventilated pit latrines and localised solar energy solutions. These types of solution do not require large teams of engineers to carry out the design and construction of complex networks, treatment works or power stations, nor large teams to operate or carry out ongoing maintenance.

Table 28 shows the minimum levels of service suggested for different environments in South Africa in 2004. The number of engineering practitioners required increases from left to right. Should plans be put in place to increase the levels of service for substantial portions of the population, then an increased number of engineering practitioners would be required.

Extent of investment in infrastructure

The AIDI, discussed in Chapter 6, is a good indicator of the extent of the infrastructure in each country and gives a sense of the level of expenditure that has taken place in the past. As discussed, without investment and a flow of funds, development cannot take place, limiting the need for engineering practitioners and the opportunities for developing graduates. Figure 28 shows that there is a strong correlation between the GDP per capita and the AIDI.

South Africa is the only country that does not closely follow the trendline. The quality of the infrastructure can be attributed to massive spending on infrastructure in the newly independent apartheid South Africa from the early 1970s to the early 1980s. The construction spending at the time remained at an all-time high for several years, the level of which was only reached again during heightened construction spending in 2008 to 2009 in preparation for the Soccer World Cup (SWC).

During the earlier period, national roads, rail, ports, airports, major dams and power stations, along with

Table 28: Levels of service

SERVICE TYPE	MINIMUM SERVICE	LEVEL 1 BASIC	LEVEL 2 INTERMEDIATE	LEVEL 3 FULL
Increasing level of service				
Water	6 kl of drinking water per month, within 200 m of each household	Communal standpipes	Yard taps, yard tanks	In-house water
Sanitation	VIP latrine or better	VIP latrine	Loflos or septic tanks	Full waterborne in-house
Electricity	50 kWh per month per household. One street light for every 4 stands or high-mast lighting	5–8 A or non-grid electricity	20 A	60 A
Roads	Residential roads to provide all-weather access to within 500 m of dwelling	Graded	Gravel	Paved/tarred & kerbs
Stormwater drainage	Must be controlled in rural and urban areas	Open earth-lined channel	Open lined channel	Piped systems
Solid waste disposal	Street refuse container within 200 m per household and weekly collection	Communal (residents)	Communal (contractors)	Kerbside

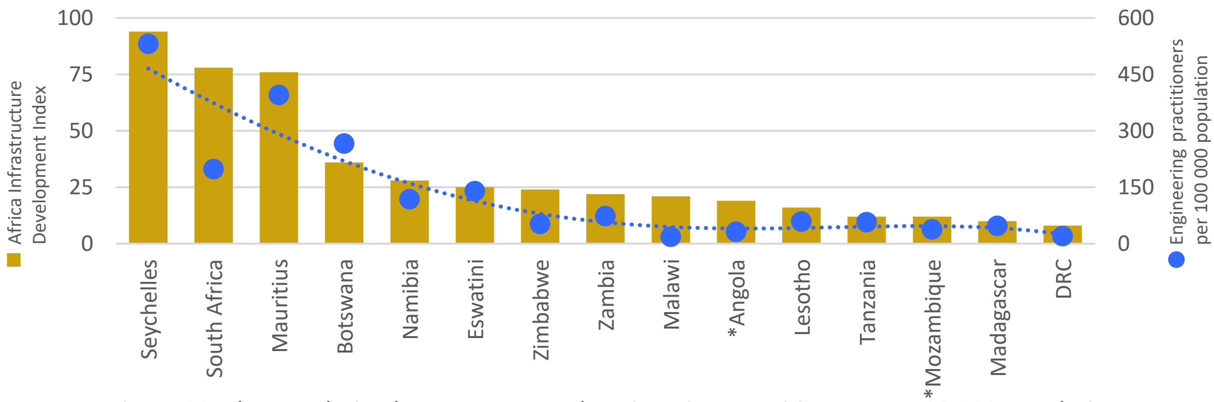


Figure 28: The correlation between AIDI and engineering practitioners per 100 000 population
(Engineers only)*

associated distribution networks and the Mossgas and oil-from-coal projects were developed.

Many foreign experts were encouraged to immigrate to South Africa to manage developments, but at the same time government offered bursaries to thousands of young people to study engineering and work as juniors on these projects. As graduate-in-training programmes had been introduced in the early 1970s, graduates were given all-round structured training over the 10 years and went on to become well-respected engineers. The number of civil engineers graduating at the time topped 350 a year, a number that had dropped to 130 by the early 2000s as demand dropped.

FILLING VACANCIES

Each country reported significant vacancies in the public sector. In some cases 50% or more of the vacancies were required to be filled in order to handle the current workload. An interesting concept of 'latent skills shortages' also exists. These occur where there are unrecognised skills gaps and the organisation copes without the necessary skills, but is not delivering the service required. Should funding be made available for vacant posts and to fill latent gaps, the numbers in industry would also increase.

ACADEMIA

The staff:student ratios in tertiary education are another factor that influences the number required. At outlined in Chapter 7, ratios of 1:75 and higher were not uncommon in SADC tertiary institutions. Should countries commit to achieving ratios of 1:15, and develop sufficient capacity to achieve the target, this will also increase the number employed.

Considering a country with 7 500 engineering students, the current number of academics at 1:75 of 100 would need to increase to 500.

MANUFACTURING

Manufacturing is important in any country, not only for producing goods required for local consumption, but also to offer employment and tap export markets to increase national income. Manufacturing has been the catalyst for growth and employment in economies that have achieved a high GDP.

The manufacturing sector is relatively small and contributes less than 10% to the GDP in many Member States. The size of the sector varies between countries and is particularly low in those at relatively low stages of development. It also continues to be resource-dependent, with low value addition and low levels of exports of advanced products. The levels of innovation and private sector investment are also low in many countries.

Table 29 shows the UNIDO classification of manufacturing into low-, medium- and high-tech. Generally, agro-processing (which in many countries holds the major share) is low-tech; plastics, basic metals and repairs are medium-tech; while machinery, electronics, etc. are high-tech. Research has shown that there are considerable differences in the employment ratios and requirements between the levels of technology.

As high-tech requires innovation, significant R&D is necessary. Furthermore, high-tech products have many components, hence require many production lines to produce a single end-product. The selling and supporting of high-tech products requires ongoing engagement, creating downstream jobs.

Table 30 shows a range of manufacturing activities and their associated multiplier effects. As manufacturing becomes more sophisticated, the job multiplier rises. Even in general manufacturing, for every manufacturing job created there are approximately 1.6–2.5 indirect jobs created. With the increasing complexity of high-tech manufacturing,

Table 29: UNIDO Classification of low- medium- and high-tech manufacturing

DIVISION	CATEGORY ISIC REV. 4	DESCRIPTION
Low technology	10	Food products
	11	Beverages
	12	Tobacco products
	13	Textiles
	14	Wearing apparel
	15	Leather and related products
	16	Wood and products of wood and cork
	17	Paper and paper products
	18	Printing and reproduction of recorded media
	19	Coke and refined petroleum products
	25 excl. 252	Fabricated metal products, except weapons and ammunition
	31	Furniture
Medium technology	22	Rubber and plastics products
	23	Other non-metallic mineral products
	24	Basic metals
	Group 301	Ships and boats
	332 excl. 325	Other manufacturing except medical and dental instruments
	33	Repair and installation of machinery and equipment
Medium-high and high technology	20	Chemicals and chemical products
	21	Pharmaceuticals
	Group 252	Weapons and ammunition
	26	Computer, electronic and optical products
	27	Electrical equipment
	28	Machinery and equipment n.e.c.
	29	Motor vehicles, trailers and semi-trailers
	30 excl. 301	Other transport equipment, except ships and boats
	Group 325	Medical and dental instruments

the number of high-end engineering skills required increases and the number of indirect jobs created rises to between 4 and 15 for every direct manufacturing job.

Analysing the manufacturing industries proved very difficult as value add or output data per UNIDO category was not available from many countries. In most cases the top three or four industries that contributed to the manufacturing GDP were listed and the rest were lumped under 'Other'. The data that was available is shown in Table 31. Unfortunately, the data per country is from different years, as shown in the country reports.

Examination of the range of products manufactured and the associated levels of technology shows that only South Africa followed by Botswana have achieved a reasonable proportion of high-tech manufacturing. The ranges of these activities are outlined in the country reports. The SADC industrialisation strategy suggests that countries should aim to increase the share of medium-and high-technology manufacturing to 30 % by 2030 and to 50 % by 2050.

Table 30: Types of manufacturing and associated jobs multiplier

TYPE OF MANUFACTURING	JOBS MULTIPLIER
General	1.6-2.5
High-tech	3.5
Microprocessor electronics	4.1
Jet engines	7-8
Electronic computers	15

In selecting the areas into which each country intends to develop, curricula should be revisited to ensure that the appropriate technology is covered, and bursaries programmes should be linked to such developments so that students and graduates can be part of developing and setting up the new processes.

An increase in the number of engineering practitioners required should be based on the percentage increase in manufacturing planned, taking into account the level of technology.

The increase in the number of high-end skills for hi-tech engineering is not limited to manufacturing but is recognised in many sectors. The South African electricity utility (Eskom) suggests that in their sector, a ratio of 1 engineer: 1 technician: 1 artisan is required for the building of hi-tech generation plants, whereas 1:2:4 is appropriate for medium-tech builds and 1:4:8 for low-tech developments.

Table 31: Classification of low-, medium- and high-tech manufacturing percentages in SADC countries

<table>
<tr><th rowspan="2">COUNTRY</th><th colspan="5">LOW TECH</th><th colspan="3">MEDIUM TECH</th><th colspan="5">HIGH TECH</th><th colspan="4">TOTAL</th></tr>
<tr><th>Food & beverages</th><th>Tobacco products</th><th>Textiles</th><th>Wearing apparel, leather, footwear</th><th>Wood, paper, printing, furniture</th><th>Petroleum, rubber, plastics</th><th>Non-metallic minerals</th><th>Metals & metal products</th><th>Chemicals & chemical products</th><th>Machinery & equipment</th><th>Electrical equipment</th><th>Medical & precision instruments</th><th>Motor vehicles & other transport equipment</th><th>Other</th><th>Low tech</th><th>Medium tech</th><th>High tech</th></tr>
<tr><td>Angola</td><td>88</td><td></td><td></td><td></td><td></td><td></td><td>7</td><td>2</td><td>3</td><td></td><td></td><td></td><td></td><td></td><td>88</td><td>9</td><td>3</td></tr>
<tr><td>Botswana</td><td colspan="2">26</td><td colspan="2">3</td><td></td><td></td><td></td><td></td><td>5</td><td>15</td><td></td><td></td><td></td><td>51</td><td>29</td><td></td><td>20</td></tr>
<tr><td>DRC</td><td>46</td><td></td><td></td><td></td><td>11</td><td></td><td></td><td></td><td>11</td><td></td><td></td><td></td><td></td><td>32</td><td>57</td><td></td><td>11</td></tr>
<tr><td>Eswatini</td><td>85</td><td></td><td>9</td><td></td><td>2</td><td>1</td><td>1</td><td></td><td></td><td></td><td></td><td></td><td></td><td>2</td><td>96</td><td>2</td><td></td></tr>
<tr><td>Lesotho</td><td colspan="2">72</td><td colspan="2">13</td><td></td><td></td><td></td><td></td><td>6</td><td></td><td></td><td></td><td></td><td>9</td><td>85</td><td></td><td>6</td></tr>
<tr><td>Madagascar</td><td>17</td><td>17</td><td>33</td><td></td><td>2</td><td></td><td>26</td><td>2</td><td>3</td><td></td><td></td><td></td><td></td><td></td><td>69</td><td>28</td><td>3</td></tr>
<tr><td>Malawi</td><td>48</td><td>25</td><td colspan="2">2</td><td></td><td>3</td><td>5</td><td>3</td><td>8</td><td></td><td></td><td></td><td></td><td>6</td><td>75</td><td>11</td><td>8</td></tr>
<tr><td>Mauritius</td><td>34</td><td></td><td colspan="2">38</td><td></td><td>4</td><td>4</td><td>3</td><td>4</td><td></td><td>1</td><td></td><td></td><td>12</td><td>72</td><td>11</td><td>5</td></tr>
<tr><td>Mozambique</td><td>37</td><td>8</td><td>2</td><td></td><td></td><td>1</td><td>6</td><td>42</td><td>2</td><td></td><td></td><td></td><td></td><td>2</td><td>47</td><td>49</td><td>2</td></tr>
<tr><td>Namibia</td><td>51</td><td></td><td>4</td><td></td><td>7</td><td></td><td>3</td><td>24</td><td>5</td><td></td><td></td><td></td><td></td><td>6</td><td>62</td><td>27</td><td>5</td></tr>
<tr><td>Seychelles</td><td>71</td><td>3</td><td></td><td></td><td></td><td></td><td>8</td><td></td><td></td><td></td><td></td><td></td><td></td><td>18</td><td>74</td><td>8</td><td></td></tr>
<tr><td>South Africa</td><td colspan="2">26</td><td colspan="2">3</td><td>18</td><td>11</td><td>3</td><td>9</td><td>11</td><td>9</td><td>2</td><td>1</td><td>7</td><td></td><td>47</td><td>23</td><td>30</td></tr>
<tr><td>Tanzania</td><td>61</td><td>9</td><td>4</td><td></td><td></td><td>4</td><td>7</td><td></td><td></td><td></td><td></td><td></td><td></td><td>15</td><td>74</td><td>11</td><td></td></tr>
<tr><td>Zambia</td><td>63</td><td></td><td colspan="2">6</td><td>18</td><td>4</td><td>1</td><td>2</td><td>5</td><td></td><td></td><td></td><td></td><td>1</td><td>87</td><td>7</td><td>5</td></tr>
<tr><td>Zimbabwe</td><td colspan="2">27</td><td>3</td><td>4</td><td>17</td><td></td><td>20</td><td>20</td><td>3</td><td></td><td></td><td></td><td>6</td><td></td><td>51</td><td>40</td><td>9</td></tr>
</table>

AGRICULTURAL ENGINEERING

In many countries the number of agricultural engineers and extension officers is low and has been reducing over the years. Given the need to support millions of rural farmers to achieve sustainability, a rethink of national policy with respect to food security, developing sustainable villages and developing agricultural engineers, scientists and extension officers could well add more numbers of engineers to the workforce. Agricultural engineers lament never having been involved in the formulation of the agricultural policy in their countries and have many ideas to share.

DEVELOPING SPECIALISTS FOR AND THROUGH PROJECTS

Countries cannot expect to develop experts in niche, particularly high-tech, areas overnight. When entering new, particularly high-tech markets or embarking on complex projects, dedicated skills development plans must be put in place. Initially, it may be necessary to use international expertise to get projects, systems or processes off the ground, but the conscious transfer of skills as discussed in *Tomorrow's Leaders* must be put in place.

In new areas, attention also needs to be paid to developing or accessing suitable qualifications, offering bursaries and ensuring that a pool of appropriate skills has been developed. In Mozambique for instance, detailed research has been carried out on the level of skills required for the emerging gas market. Bursaries are being offered for students to study in this field and local qualifications are being developed. Turning to the SKA project being rolled out in several SADC countries, a skills plan that includes the training of a range of engineers and scientists all the way up to PhD level has been put in place to ensure a pool of experts able to work at the cutting edge.

The philosophy of the publication titled *Skills for and through SIPs*, which is the skills plan for the development of Strategic Integrated Projects in South Africa, says it all. Skills need to be developed for particular projects or tasks, but considerable skills can be developed when working on projects. By planning in advance, it is possible to develop skills for projects and through projects once they commence.

WHAT NUMBERS?

There is no one answer to what numbers? Each country and each industry has different needs which must be analysed on a case-by-case basis. The numbers will vary according to the type of development, the level of service and the level of technology.

Using the Seychelles ratio of 540 engineering practitioners to 100 000 population as a target to which to strive, it is possible to see how, in time, this number may be achieved in other countries.

Considering Madagascar for instance, with 11 000 engineering practitioners (45 per 100 000 population) and an AIDI of 10.73, it is conceivable that in developing substantially more infrastructure to achieve an index of 100 (i.e. almost 10x the current number) seven to eight times the current number of engineering practitioners associated with infrastructure would be required, increasing the number by 26 000. Much of the existing infrastructure is at the lowest level of service, with many isolated rural settlements. Increasing the level of service to networked solutions would need two or three times more engineering staff, increasing the number in infrastructure from 29 250 to perhaps 70 000. Increasing manufacturing and the percentage of high-tech manufacturing may require a further 7 000. Addressing current vacancies may require a further 2 000 to 4 000. To achieve a 15:1 ratio of students to lecturers would require more academics and several thousand more are required in agricultural engineering to enhance farming methods and productivity. This could take the total number to some 85 000, representing almost 350 engineering practitioners per 100 000 population – a far cry from the existing 45.

As per the discussion in the previous chapter, this cannot happen without investment in infrastructure, followed by ongoing maintenance. If funds are not forthcoming and development does not take place, there will be no need for more engineering personnel and no work on which to train young graduates. Furthermore, if higher levels of service are not possible in practice due to geographic and logistical constraints, there will be no need for the number to increase from 29 250 to 70 000 for infrastructure as postulated above, and the ratio will be consistently lower than in countries where a large percentage receive the highest levels of service.

Varying ratios of engineering practitioners to population relating to types and levels of service are not limited to developing countries. In the UK, the LFS reports some 770 000 engineers and engineering technicians, i.e. a ratio of about 1 160 practitioners to 100 000 people. The LFS survey in the USA shows some 2.76 million practitioners, which equates to 850 per 100 000 population, a difference of over 300 practitioners per 100 000. Given the vastness of the USA and the many isolated areas, it is possible that a higher portion of the population is served by off-grid solutions such as diesel generators, dry sanitation and rainwater harvesting. The installation of these services is the domain of the artisan and maintenance of some services can be handled by the user, whereas in the UK, most consumers are served from national grids. These and many other factors need to be considered when comparing ratios.

Combining engineering workforce estimates and registration data from each country suggests that there are almost 230 000 engineering practitioners in the region, just under 21% of whom are professionally registered as shown in Table 32. It should be noted that registration is in place in only 12 SADC countries, and in several countries only one or two of the three categories shown are eligible for registration.

The number graduating in 2015 represented just over 11% of the workforce, which is a large number to absorb in the absence of meaningful work. Anecdotally the graduation numbers have increased significantly in several countries since 2015, contributing to the increasing pool of unemployed graduates.

SKILLS PLANNING

The number of engineers is approximately 115 000, which is orders of magnitude lower than the numbers suggested by the OECD.

Table 32: Estimated engineering workforce, registration, graduation and gender statistics for the region

CATEGORY / NUMBER	TOTAL IN THE WORKFORCE	REGISTERED		GRADUATES		GRADUATES AS A % OF THE WORKFORCE
		REGISTERED	% REGISTERED	IN 2015*	% FEMALE	
Engineers	114 579	34 722	30%	9 875	22.0%	9%
Technologists and technicians**	114 281	12 746	11%	15 607	24.7%	14%
TOTAL	**228 860**	**47 468**	**21%**	**25 482**	**23.7%**	**11%**

* Totals are understated as graduation data from some countries is incomplete – see Figure 23

** Technologist and technician categories are not recognised in all countries – see Table 24

However, before rules of thumb are used to decide on the number per discipline to be educated and trained, it is essential that robust research and planning is carried out to ensure that the numbers to be trained and the needs of each country do indeed match.

When asking employers about this, however, it is essential to determine the level at which their shortages exist. All too often the cry is heard '*we can't find engineers*', but there are thousands of young engineering graduates who cannot find employment. What employers really mean is that they can't find experienced engineers. Questionnaires need to be carefully framed to determine the experience levels and specialisations required, rather than just asking about the number required per occupation. The number to be trained must be based on the demand, i.e. the types of services, industries and numbers and disciplines actually needed.

WHAT NEEDS?

Countries lament the shortage of engineers, but in general they are not appointing or retaining engineering practitioners across all levels in the public sector and those appointed generally do not have the authority to make technical decisions.

Countries are not making use of local engineering skills often favouring international resources nor are they investing sufficiently in infrastructure and local industrialisation initiatives to absorb and train more engineers. This not only leads to a loss of local experienced engineering practitioners, but limits the opportunities to develop specialists.

Furthermore, with poor schooling, the proliferation of tertiary institutions offering poor quality or unaccredited engineering qualifications and the lack of training of graduates and young professionals, the environment is simply not conducive to producing experienced local engineering practitioners.

To develop the appropriate number of engineers, engineering technologists and engineering technicians in the region there is a **need** to:

- Determine the demand per discipline and sector in each country
- Enhance mathematics and science teaching in primary and secondary education
- Attract high calibre entrants into engineering studies
- Create regional engineering qualification standards and ensure that they conform to international best practice
- Address the capacity of tertiary education to improve the quality of engineering graduates and ensure that qualifications align with agreed regional standards
- Rationalise engineering studies into strong institutions
- Address graduate training
- Align registration processes in the region and ensure that they conform to international best practice
- Develop mid-careers professionals to become the specialists and leaders of tomorrow.

The above are all critical to address the quality of engineering skills in the region and to develop expertise. This is essential to support service delivery and the growth, and in some cases, the viability of the industrial sector.

Should economic growth not take place, there will be no need for the numbers to increase. The engineering activities on which to develop graduates will also be limited. Therefore, in addition to the above, to support growth, countries **need** to:

- Fill key positions with experienced engineering professionals, able to plan, develop, manage and deliver functional infrastructure, who have been assigned the authority to make engineering decisions
- Review and increase tariffs where appropriate, enhance domestic revenue collection and demand management, and ring-fence funds collected for infrastructure development and maintenance
- Invest in and expand infrastructure development and associated maintenance
- Support research and development to emerge with new technologies to contribute towards diversification of the economy and job creation
- Review and amend policies where necessary to be investor friendly
- Capitalise on the abundant mineral reserves in the region through mining and beneficiation and develop international markets
- Stimulate and support agro-processing and develop value chains
- Grow the manufacturing sector, particularly the high-tech sector
- Balance the need for local job creation with liberalisation
- Align policies and criteria for the appointment of international service providers and the involvement of foreign investors in the engineering sectors and ensure that local engineering skills are developed and harnessed,

and materials and equipment are sourced locally where practical

- Invest in and enhance agricultural productivity and support the development of smallholders
- Develop outlets for agricultural products and the associated logistics for collecting, storing and transporting goods to markets
- Develop infrastructure, health and education facilities in rural areas to grow rural communities and support de-urbanisation
- Invest in robust central datasets on which to make development decisions.

In individual country reports, detailed recommendations have been made. Each country's **needs** are different. Once firm development plans are in place, skills plans must be developed with the engineering community to ensure that supply will match the demand.

Many regional trends and **needs** have been identified for which solutions have been suggested in Chapters 7 to 11. Collaboration with the engineering community will be essential to ensure alignment of approaches and to support mobility of engineering professionals.

ENGAGEMENT WITH THE PROFESSION

Throughout the research, it was surprising to find how little interaction there was between professional bodies and engineering ministries and utilities. Professional bodies represent the range of professionals – those from academia, consulting, contracting, manufacturing, mining, production and all the disciplines and subdisciplines associated with these sectors. Furthermore, membership includes those in both the public and private sectors.

It is in the business interests of private sector companies to keep up with the latest trends and technologies, and to carry out or commission research. It is important that their hands-on experience and pioneering is shared with government departments to offer direction and, in some cases, train and develop public sector staff.

It is suggested that a *National Engineering Advisory Team (NEAT)* be constituted per country to engage with government as and when considered necessary. It should be composed of a pool of experts nominated by the range of associations, institutions and engineering boards in each country, including academics and practitioners from the private and the public sectors, covering all disciplines. The names of the team members should be shared on all organisations' websites, and the existence of the NEAT should be widely publicised. The composition should be a collegial arrangement across all bodies representing engineering, with no one body taking over, or imposing its views. Government should be in a position to call upon members of the pool for advice, or when issues arise that need reaction, and team members should work together to develop input as required to address engineering matters.

CONCLUSION

The future can be anything we design it to be. Member States are blessed with many natural resources and the climate supports extensive agricultural production. It is time to capitalise on the opportunities for agro-processing, mineral beneficiation and downstream processing to support growth, infrastructure development, job creation and address poverty.

With a growing cadre of new leaders and the increasing calls for change and regional development, it is time to craft and implement agreements built on partnerships in the interests of the region. With the right policies, plans, investment and commitment in place, the aspirations of Agenda 2063 and the Industrialisation Strategy can be met.

Engineering professionals must be harnessed and are ready to support development – the words of Lesotho-born, Seetella Makhetha, when he launched the *Credo of the African Engineer* on becoming President of the South African Institution of Civil Engineering (SAICE) in 2011, ring true.

The Credo of the African Engineer

I am an Engineer and in my profession I take deep pride. To it I owe solemn obligations. Since the origins of humanity on the continent of Africa, human progress has been spurred by the engineering genius.

Engineers have made usable nature's vast resources of material and energy for humanity's benefit. Engineers have vitalised, and turned to practical use, the principles of science and the means of technology. Were it not for this heritage of accumulated experience, my efforts would be feeble.

As an Engineer, I pledge to practice integrity and fair dealing, tolerance and respect, and to uphold devotion to the standards and the dignity of my profession, conscious always that my skill carries with it the obligation to serve humanity by making the most sustainable use of Earth's precious resources.

As an Engineer, I shall participate in none but honest enterprises. When needed, my skill and knowledge shall be given without reservation for the public good. In the performance of duty and in fidelity to my profession, I shall give the utmost.

SOURCES OF INFORMATION

Data and information were gathered during meetings, interviews, telephone and Skype conversations, and via email. SADC reports, master plans and strategies and many standard international sets of data as listed in Chapter 5, *Research Approach,* were also consulted. Comprehensive documents focusing on specific issues as listed below were additional sources of information.

AfDB (African Development Bank). 2018. *African Economic Outlook 2018.* Abidjan, Côte d'Ivoire: AfDB.

African Financials/Copperbelt Energy (CEC.zim). 2018. *Engineers challenged to be solution oriented*. Available at: www.africanfinancials.com/engineers-challenged-to-be-solution-oriented.

American Society for Engineering Education. Committee on Evaluation of Engineering Education. 1955. Appendix. *Summary of the Report on Evaluation of Engineering Education*. Reprinted from *Journal of Engineering Education*, September 1955: 25–60. Available at: www.asee.org/papers-and-publications/publications/The-Grinter-Report-PDF.pdf.

Arum, R. and Roksa, J. 2011. *Academically Adrift: Limited Learning on College Campuses*. Chicago, IL: University of Chicago Press Books.

Blackie, M., Mutema, M. and Ward, A. 2009. *A study of agricultural graduates in eastern, central and southern Africa: Demand, quality and job performance issues.* ASARECA/RUFORUM THRUST 4 report. (Also Paper presented at the Ministerial Conference on Higher Education in Agriculture in Africa, 15–19 November 2010, Kampala, Uganda.)

Budlender, D. 2014. *Migration and employment in South Africa: Statistical analysis of the migration module in the Quarterly Labour Force Survey, third quarter 2012.* MiWORC Report No. 5, Johannesburg: African Centre for Migration & Society, University of the Witwatersrand.

Cappelli, P. 2017. *The skills gap is a myth*. Society for Human Resource Management. Available at: www.shrm.org/hr-today/news/hr-magazine/1217/pages/the-skills-gap-is-a-myth.aspx.

CDE (Centre for Development and Expertise). 2004. *From laggard to world class.* Johannesburg: CDE.

CDE. 2010. *Options for Talented learners from disadvantaged backgrounds*. Johannesburg: CDE.

Crush, J., Dodson, B., Williams, V. and Tevara, D. 2017. *Harnessing migration for inclusive growth and development in southern Africa.* Vienna: International Centre for Migration Policy Development, and Waterloo, ON: Southern African Migration Programme.

DCED (Donor Committee for Enterprise Development). n.d. Link between economic growth and employment. *DCED Newsletter*. Available at: www.enterprise-development.org/what-works-and-why/evidence-framework/link-between-employment-and-economic-growth [Accessed on 29 April 2018].

Desnoyers, M. 2011. *The relationship between economic growth and employment.* Available at: www.disnat.com/en/learning/expert-articles/marc-desnoyers/the-relationship-between-economic-growth-and-employment [Accessed on 29 April 2018].

Eagar, P.G.W. 2008. *Emigration potential of South African engineers*. MBL Dissertation, Pretoria: University of South Africa (UNISA).

Encyclopaedia Britannica. 1969 edition. Article on Engineering education. Chicago, IL: William Benton.

Esnault, D./AFP. 2018. *Massive infrastructure spending needed in Africa says report.* Available at: www.news24.com/Africa/News/massive-infrastructure-spending-needed-in-africa-says-report.

FAO (Food and Agriculture Organization of the United Nations). 2017. *The state of food and agriculture. Leveraging food systems for inclusive rural transformation.* Rome: FAO. Available at: www.fao.org/3/a-i7658e.pdf.

Flanigan, R.L. and Porter, D.S. 2015. *The influence of the Grinter Report on engineering technology and the emergence of manufacturing engineering technology*. Paper presented at the 2015 Conference for Industry and Education Collaboration, American Society for Engineering Education, 4–6 February 2015, Palm Springs, CA.

Froyd, J.E., Wankat, P.C. and Smith, K.A. 2012. Five major shifts in 100 years of engineering education. *Proceedings of the IEEE*, 100 (Special Content): 1344–1360. DOI: 10.1109/JPROC.2012.2190167.

Kapsos, S. 2005. *The employment intensity of growth: Trends and macroeconomic determinan*ts. Employment Strategy Paper 2005/12, Geneva: Employment Strategy Department, International Labour Office.

Khan, A.R. 2007. *Growth, employment and poverty: An analysis of the vital nexus based on some recent UNDP and ILO/SIDA studies*. Working Paper 49, United Nations, Department of Economics and Social Affairs.

Lawless, A. 2005. *Numbers and needs. Addressing the imbalances in the civil engineering profession*. Midrand: SAICE.

Lawless, A. 2008. *A structured approach to workplace training of civil engineering technicians in South Africa using retired engineering capacity*. Unpublished doctoral dissertation, University of Johannesburg.

Lusaka Times. 2014*. Zambian engineers are maintenance engineers and not innovative-Prof Chirwa*. 21 April 2014. Available at: www.lusakatimes.com/2014/04/21/zambian-engineers-maintenance-engineers-innovative-prof-chirwa.

Martin, P. 2005. *Managing labour migration: Professionals, guest workers and recruiters.* Paper presented at the United Nations Expert Group Meeting on International Migration and Development, 6–8 July 2005, New York.

Mwamila, B.L.M., Mkamba, A.O. and Mushi, E. 2004. *Capacity building initiatives by the Engineers Registration Board*. Dar es Salaam, Tanzania: Engineers Registration Board.

News24. 2018. *'Massive' infrastructure spending needed in Africa*. 18 January 2018. Available at: www.news24.com/Africa/News/massive-infrastructure-spending-needed-in-africa-says-report.

Onyancha, R., Siame, J., Musonda, K. et al. 2015. *A review of engineering education in Zambia for the 21st century. Part I. Historical, current and future trends.* Paper presented at the Conference of the Engineering Institution of Zambia, 2 May 2015, Livingstone, Zambia. Available at: www.researchgate.net/publication/297693426_A_Review_of_Engineering_Education_in_Zambia_for_the_21st_Century_Historical_Current_and_Future_Trends_Part_I

Patra, S.K. and Muchie, M. 2017. Engineering research profile of countries in the African Union. *African Journal of Science, Technology, Innovation and Development*, 9(4): 449–465.

Revans, R. 1981. The nature of action learning. *OMEGA: International Journal of Management Science*, 9(1): 9–24.

SADC. 2013. *SADC Labour migration policy*. Report SADC/ELSJTSCM/1/2013/9, Geneva: International Migration Programme, International Labour Office.

SADC. 2015. *SADC Industrialisation Strategy and Roadmap 2015–2063 (final).* Approved by the Summit on 29 April 2015.

SADC. 2017. *Action Plan for SADC Industrialisation Strategy and Roadmap.* Approved by the Summit in Lozitha, Swaziland on 18 March 2017.

SADC National Qualifications Framework. 2018. *Report on the alignment of the South African National Qualifications Framework (SANQF) to the Southern African Development Community Qualifications Framework (SADCQF).*

SAICE (South African Institution of Civil Engineering). *Code of Best Practice: Practical Guide to Minimum Standards for Civil Engineering Tertiary Education*. Being finalised.

Senker, P. 2000. What and how do engineers learn? In: Rainbird, H. (Ed.). *Training in the Workplace: Critical Perspectives to Learning at Work*. London: Macmillan, pp 169–188.

Teach First n.d. *What you need to join our programme.* Available at: www.teachfirst.org.uk/our-programme/about-the-programme/requirements.

The Guardian. 2014. *Tanzania: Large-scale farming turns small farmers into mere labourers*. 18 February 2014. Available at: www.theguardian.com/global-development/2014/feb/18/tanzania-large-scale-farming-small-farmers-labourers.

United Nations. 2014. *UN General Assembly's Open Working Group proposes sustainable development goals* Press release, 22 July 2014. Available at: www.sustainabledevelopment.un.org/content/documents/4538pressowg13.pdf [Accessed on 21 January 2018].

United Nations. 2015. *Trends in international migrant stock. Migrants by destination and origin*, 2015 revision. UN Department of Economic and Social Affairs, Population Division (United Nations database, POP/DB/MIG/Stock/Rev. 2015).

WFEO (World Federation of Engineering Organizations). 2018 (June). *Paris Declaration (WFEO – UNESCO Declaration) – Advancing the Sustainable Development Goals through Engineering.* Session 2, WFEO Global Engineering Congress, Engineering Education for Sustainable Development, 24 June 2018, Paris: WFEO.

WFEO (World Federation of Engineering Organizations). 2018 (October). *Engineering 2030. A plan to advance the achievement of the UN Sustainable Development Goals through engineering. Progress Report No. 1.* Opening Address by Dr M. Kanga, President of the WFEO, Engineering Congress – GEC2018, 22–26 October 2018, Paris: WFEO.

Williams, G., Cunningham, S. and de Beer, D. 2014. *Advanced manufacturing and jobs in South Africa*. Pretoria: Mesopartner Africa.

Part 3
Country Reports

PART CONTENTS

Detailed findings and recommendations per country are contained in the following section. Each country report looks at the different engineering sectors, and developments planned or required to give a sense of the need for engineering skills. The numbers per country are established, graduations and possible growth scenarios are considered to determine the adequacy of the supply side to feed demand. The reports are structured as follows:

- The economy
- Engineering activities
- Education, training and professional development
- The workforce
- Engineering Numbers and Needs
- Key recommendations
- Acknowledgements
- Sources of information

The countries are ordered as follows:

ANGOLA
BOTSWANA
DEMOCRATIC REPUBLIC OF THE CONGO
KINGDOM OF ESWATINI
KINGDOM OF LESOTHO
MADAGASCAR
MALAWI
MAURITIUS
MOZAMBIQUE
NAMIBIA
SEYCHELLES
SOUTH AFRICA
UNITED REPUBLIC OF TANZANIA
ZAMBIA
ZIMBABWE

ANGOLA

ANGOLA is the seventh-largest country in Africa and is bordered by Namibia to the south, the Democratic Republic of the Congo to the north, Zambia to the east, and the Atlantic Ocean to west.

In 2018, Angola was the fifth-largest economy in Africa and the second largest in SADC after South Africa. In 2015 it was the second-largest oil-producing country in Africa and the sixteenth-largest in the world. Oil production accounts for 40% of Angola's GDP and diamonds somewhere between 2% to 5%, depending on world prices.

In 2017, the country was classified as a lower middle-income country. Just over 30% of Angolans live below the international poverty line and few have access to formal employment. With half the population under the age of 20, finding employment is a major problem among the youth, and many tertiary education institutions have been opened to skill the youth and create employment opportunities for them.

Angola has the highest rate of diarrheal disease in the world as a result of inadequate water and sanitation services, which are said to be the least developed in Africa.

The capital city is Luanda. It is the most populous and important city, as it is a primary port and major industrial, cultural and urban centre. Angola is a highly urbanised country, with some 62%. of its population living in urban areas. With limited progress having been made towards industrialisation, millions live in un-serviced settlements known as *musseques*, and many displaced by civil war still live in refugee camps.

Although the economy has grown significantly since emerging from the civil war in 2002, the slump in the oil price, the cost of corruption, and the huge investments in inappropriate housing solutions resulted in zero growth in 2016. This has resulted in thousands of Chinese and Portuguese workers leaving the country. The population remaining are grappling with an inflation rate of 30% and a shortage of dollars needed to import products.

To address the challenges, the new president, Joao Lourenco, elected in August 2017, has pledged to fight corruption, diversify the economy and attract foreign investment. He has also called on Angolans abroad to invest their money back home.

THE ECONOMY

Prior to 1975, the Angolan economy was based on agriculture and mining, and the country was a large exporter of fruit, coffee and sisal. Agricultural production, gold and diamond mining virtually ground to a halt during the war years and infrastructure was destroyed.

Angola continued, however, to export oil, which has been its largest export for some four decades. The surging oil prices from the early 2000s allowed the economy to boom. Foreign investors flocked to Angola, and its oil-for-finance deal with the Chinese

Table 1 : Angola metrics

Population	
Total	28 674 000
Urban	62.8%
Rural	37.2%
Poverty, HIV, Unemployment	
Below the international poverty line	30.1%
HIV-positive	1.1%
Unemployment	24.2%
Human Development Index	0.532
Electricity	
Production kWh	10.2bn
Consumption kWh	9.04bn
Airports and Ports	
Airports	176
- Paved	3
- Unpaved	173
Ports	17
Kilometres of Services	
Roads	51 429
- Paved	5 349
- Unpaved	46 080
Rail	2 852
Pipelines	1507
- Gas	352
- Oil	1 065
- Refined products	90
Waterways	1 300
Africa Infrastructure Development Index	19.04
Access to Services	
Access to safe drinking water	44%
- Urban	57%
- Rural	22%
Access to improved sanitation	60%
- Urban	82%
- Rural	26%
Access to electricity	30%
- Urban	46%
- Rural	18%
Telephones	304 493
Mobile phones	13 000 124
Internet users	13%

saw huge growth in the construction industry, as the government launched a string of projects, from highways to satellite towns and flashy high-rise buildings.

The economy suffered a setback with the economic crisis of 2008 and has been hard hit by lower oil prices since mid-2014. Angola now finds itself with a reduced amount of oil to sell, as most of its production goes to China to repay the debt, leaving little means to earn foreign currency. In Luanda, construction activities have virtually ground to a halt and many buildings remain unfinished. Diversification is key to shift the economy away from its reliance on mining exports. The development and rehabilitation of infrastructure and developing the agricultural and manufacturing sectors are key priorities. To this end, the Production, Export Diversification and Import Substitution Programme (PRODESI) has been launched.

PLANS AND STRATEGIES

To address development, several important plans and policies have been drawn up, including:

- **Angola Visão 2025** which is the long-term development strategy aimed at eradicating poverty, from which many of the plans below were developed.
- **National Development Plan (2018–2022)** which encompasses a strategy to create a network of development zones or hubs to address '*...stability, growth and jobs*'. Infrastructure to be developed includes widespread access to electricity, water and transport.
- **Energy and Water Action Plan (2018–2022)** which reinforces the focus on large hydroelectric plants to expand energy capacity and the need to expand access levels to safe drinking water and sanitation facilities in both urban and rural areas.
- **The Strategic National Accessibility, Mobility and Transport Plan (PENAMT)** which proposes the development approach for a nationwide transport network, composed of roads, railways, inland waterways, ports and airports.
- **National Industrialisation Programme (PIANG) (2013–2017)** which gives priority to agro-processing, textiles and clothes, footwear, wood processing, furniture, paper, chemicals and pharmaceuticals, minerals and non-metallic construction material, basic metals and metal products.

ENGINEERING ACTIVITIES

Figure 1 shows the contribution of engineering-related economic activities to the country's GDP. By far the largest sector is mining, with construction second. Considering each in turn will give a picture of the activities, trends, challenges and opportunities for the engineering profession to contribute to Angola's growth and return to prosperity.

AGRICULTURE

Angola went from being a self-sufficient exporter to a net importer of food. The civil war displaced more than four million people and damaged the local infrastructure. Recognising the need to curb imports and increase exports, the government has made the agricultural sector a priority. Programmes have focused on the clearing of landmines remaining after the civil war, the development of family farming and commercial agriculture, and the construction and rehabilitation of irrigation projects. Landmines still present a serious challenge, and clearing is a slow, tedious process of locating and de-activating one at a time. At the current rate of funding it is estimated that it will take until 2040 to clear all landmines, but it is hoped that with increased funding clearing will be completed by 2025.

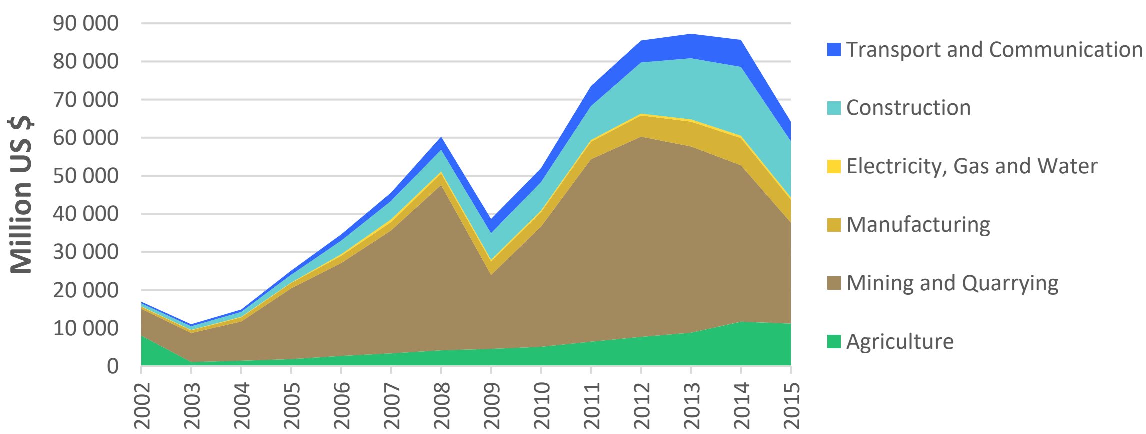


Figure 1: GDP per engineering-related economic activity (57% of the GDP)

ANGOLA

Subsistence farming

Two-thirds of the working population rely on the land for food, income and employment, of which some 80% are smallholders. The latter cultivate very small plots of land, with very low agricultural productivity.

Before independence in 1975, Angola had a flourishing tradition of family-based farming and was self-sufficient in all major food crops, except wheat, and exported many crops. Return to productivity is proving to be difficult as families have left the land and because poor transport infrastructure, the lack of refrigeration and storage facilities, etc. hamper delivery to markets. As a result, there is a high level of food wastage. In the drier areas, developing irrigation systems is vital for increasing and sustaining productivity. Greenhouses also need to be considered for extending the growing season.

Commercial farming

Private sector agriculture is expanding with several large agro-industry growers, mostly involving Portuguese, Brazilian and Israeli investors either independently or through joint ventures. Chinese participation in Angola's agriculture focuses on rice production.

Biocom, a partnership between Sonangol, the investment fund Cochan, and Brazil's Odebrecht, has set an aggressive deadline to produce 256 000 tons of sugar by 2020 on its 1 million acre farm, which will provide for 50% of Angola's domestic consumption, 33 000 m^3 of ethanol and 235 000 MW of electricity. The Castel Business Group has invested in the planting of cereal crops to reduce the import of raw material for beer production.

The Angolan government is encouraging domestic wheat production to replace flour imports and corn production to meet domestic demand (human and animal feed) by 2020. With the introduction and improvement of low-priced fertilisers and the increasing availability of agricultural machines, a large increase in the production of wheat, corn, soya beans and rice is planned for the coming years.

The Angolan Government initiated PRESILD (Programme for Restructuring of the Logistics and Distribution System of Products Essential to the Population) to support domestic agricultural production and distribution. In 2014, the Ministry of Commerce inaugurated the Logistics and Distribution Centre, 'CLOD-Luanda', a 50 000 m² facility with capacity for 312 800 metric tons of fresh produce per year. It planned to build 11 additional logistic and distribution centres nationwide.

Given the need to re-establish the agricultural sector, areas in which engineers need to play a significant role include:

- Irrigation systems (dams, pumps, pipes, etc.)
- Equipment for seeding, planting and harvesting grains and horticultural crops
- Livestock production equipment and technologies, and food-processing equipment
- Post-harvest facilities, including silos, dryers, cold chain solutions (refrigeration/warehousing)
- Development of forestry production lines
- Rehabilitation and construction of infrastructure
- Provision of technical support.

The Ministry of Agriculture and Forestry employ over 800 agricultural professionals who advise on and lead development in crop and livestock production, irrigation, storage and mechanisation, and undertake research, among others.

Forestry

The forestry sector in Angola represents an important potential for the country's economy. There is a total of 53 million ha of natural forest, 148 000 ha of planted forests, and 31 wood-processing industries, with an installed production capacity of around 1 210 m³ per day. Deforestation is a challenge for various reasons, including development and the use of wood for charcoal. A programme to expand the gas supply network is under way, as it is mainly the lack of gas that leads rural families to resort to charcoal.

Transporting wood as a raw material for manufacturing is a challenge, as most roads need urgent intervention, construction or rehabilitation, resulting in high transport costs.

Fisheries

Fisheries have been referred to as the 'engine of economic diversification'. The Support Fund for the Development of the Fisheries and Aquaculture Industry (FADEPA) has contributed to the growth in fishing by expanding infrastructure on land and renewing the fishing fleet. As a result, firms have, through technology and innovation, turned to freezing thousands of tons of fish per year, moving away from the older practice of salting and drying fish. Technology includes conveyors for fish to be transported to the cold tunnels, isothermal panels, compressors, evaporators and the use of R404 gas instead of ammonia, because it guarantees better freezing.

Challenges faced by the sector are the lack of continuous energy to keep refrigeration units going, necessitating the use of generators, the lack of a local can-making factory and the lack of spare parts, which are manufactured internationally and have long lead times. Aquaculture is still in its infancy but is being promoted by the Ministry of Fisheries and Sea.

MINING AND QUARRYING

Angola's natural resources include phosphates, iron ore, diamonds, petroleum, bauxite, uranium, feldspar and petroleum. In addition, the country has abundant reserves of salt, gypsum, granite, cement and beryllium, and undeveloped reserves of zinc, wolfram, vanadium, tungsten, silver, quartz, nickel, mica, manganese, lignite, lead, gold, copper and clay. To diversify away from oil, investment projects include:

- 23 new diamond, gold, phosphate, iron ore, copper and natural stone explorations
- The mining of iron ore in Cutato to produce pig iron, which includes the construction of a blast furnace, a crushing plant and charcoal production plants.

Given the average daily oil production of 1.6 million barrels in February 2017, diamond production of 8 934 000 carats in 2016 and plans to develop new mines and rework old mines, significant numbers of mining and petrochemical engineers and metallurgists are required to support this sector. The Ministry of Mineral Resources and Oil is setting up a dedicated institution to train petrochemical engineers, which is expected to produce its first graduates by 2021.

To attract foreign investment in the sector, the country needs to improve its electrical capacity and upgrade its dilapidated roads.

MANUFACTURING

Angola's manufacturing and processing concerns are predominately private sector enterprises and include: food and beverages; clothing and textiles; timber, pulp and paper; engineering and metal industries, plastics and chemicals. Diversification is slowly taking place. Food and beverages were the only industries in the sector in the early 2000s. By 2011, 15% of the MVA came from other industries as shown Figure 2 and by 2015 this had grown to 18% as the revival of the textile industry began to contribute.

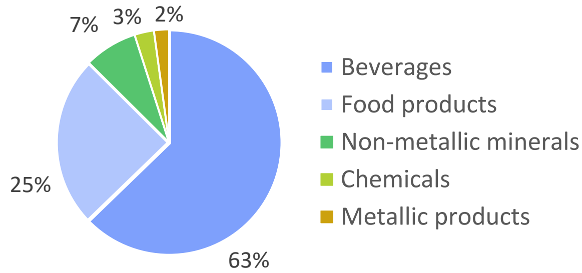


Figure 2: Manufacturing value add per subsector, 2011
(CEIC)

Although industrial parks have been developed and many more are planned, the existing parks are said to be outdated, or have inadequate infrastructure. Further obstacles facing entrepreneurs include: limited supplies of water and energy; financial constraints and policies; land ownership; the lack of local managerial and technical skills; and the high cost of hiring external expertise.

Food and beverages

Currently, Angola is an importer of canned foodstuffs, but given the plans to expand agricultural production, canning of fruit, vegetables, juice concentrates, jams and jellies (preserves) is under consideration. This requires that the existing canning plant is resuscitated or a new one is developed.

Wheat processing is being increased in Luanda and Lobito with plants producing flour, bran and animal feed. A vinegar factory, opened in 2017, will be expanded to produce seasoning, and an animal feed plant opened in 2014 to produce feed for poultry and pigs will support increased local egg production. Sugar refining is on the increase and local consumption is planned to be fully met by 2020/2021. As outlined under *Fisheries*, the freezing and canning of fish is also on the increase.

International name brands such as Nestlé and Mondelēz are well established, producing confectioneries and cereals, among others.

With regard to beverages, there are six active breweries, some of which import hops and malt, while others grow their own crops locally. There are many small distilleries making sugar-based liqueurs. Coca-Cola has five factories and manufactures an average 800 million litres of soft drinks per year. Nampak Bevcan Angola has a beverage can factory which will reduce the number of cans that need to be imported for the growing market. With some 40 beverage companies, the quantities produced in Angola meet local demand.

Textiles and clothing

The government is committed to the Programme for the Revitalisation of Cotton Production which includes the recovery, creation, expansion and modernisation of the textile industry. Plans are in place to develop 10 000 ha with drip irrigation at the Capanda Agro-industrial Complex (Malanje). Three textile factories have been modernised, namely:

- Textang II in Luanda which focuses on the manufacture of fabrics for making uniforms will produce 9 million metres per year
- Satecin Cuanza Norte which will produce over 300 000 items of knitwear and 480 000 m of denim fabric a month
- África Têxtil in Benguela which will produce 120 000 blankets, 1.8 million sheets and 12 million towels a year.

The three plants will need more than 24 000 tons of cotton fibre annually and more cotton ginning and pressing plants will be required.

Timber, pulp, paper and packaging

Plans are afoot to develop a new paper production industry in the former industrial complex of the Angola Pulp and Paper Company (CCPA). With regard to existing production, several companies manufacture hygiene products such as baby diapers, sanitary napkins, serviettes, toilet paper, industrial rolls, hand cloths and other related products, and the expansion of various facilities is planned.

There is limited packaging production, hence the launch of a cardboard packaging factory in 2017, focused on the fishing industry, was welcome.

Natural forests are a source of raw material, mainly to produce furniture and poles, plywood, doors and frames for the construction and electricity sectors. Once the roads have been upgraded, a resurgence of Angola's furniture industry is expected. Prefabricated wooden houses are also built using species such as Maçaranduba and Angelim vermelho, which have great natural durability.

Plastics, chemicals and other non-metallic mineral products

Plastic products for industrial and domestic applications, including packaging material, films and coatings, containers, electrical conduits, a range of pipes, moulded items, kitchenware and garden furniture, are among the products manufactured, mainly for local consumption. Exports to Zambia have commenced and plans are in place to sell furniture and domestic utensils labelled 'Made in Angola' to neighbouring countries, including the DRC.

Over and above the massive petrochemical industry, the range of chemical products includes paints, hardeners, seals, waterproofing, body cream, skin lotion, shower gel, talcum powder, balm, soaps, detergents and other cleaning materials.

Cement production has grown exponentially since 2002 and the five plants in operation together have excess capacity, which is available for export.

Pharmaceuticals

The Angolan government has approved the privatisation of the state pharmaceutical company Angomédica, with an expectation that the new owners will supply medicines and serums, and upgrade the laboratory facilities, to reduce dependence on imported medication. The new Angomédica is composed of three initiatives: the first, a manufacturing unit in Luanda, is expected to produce 20 million tablets per month, followed by the production of 40 million units per year of serum in a second factory, and thirdly, the construction of the Benguela Pharmaceutical Industrial Node.

Computer, electronic and optical products, and electrical equipment

With regard to electrical goods and appliances, Inovia, a 100% Angolan-owned company with private capital, was the first Angolan company to produce electrical appliances and consumer electronic products locally and is the first Angolan brand of appliances made by Angolans. SOMETIM constructed an electrical panel production plant in Luanda in 2014, which employs 33 Angolan electricians and eight foreigners, specifically trained to meet the need for electrical switchboards in the most diverse sectors. Judona Africa will soon commence with the manufacture of transformers.

Metal industries, machinery and equipment

A new steel mill with capacity to produce 500 000 tons of steel per year (almost twice the demand). has been developed, which will reduce the volume of imports. The first source is scrap, collected nationally, which is mixed with lime and an imported alloy to produce steel. The use of scrap finally addresses the recycling of war wrecks, guns and other discarded and waste products.

Manufacturing of cars under licence from Nissan commenced in 2009 and manufacture of car parts commenced in 2016. By 2014, some 30 000 vehicles per year were being assembled. As a result of these investments, machinery, including electronic equipment, was listed as the third-highest export in June 2017.

ELECTRICITY, GAS AND WATER

Electricity

Angola produces more electricity than it consumes. However, only 30% of the population has access to electricity, made up of 46% of the urban population and 18% of the rural population in 2013.

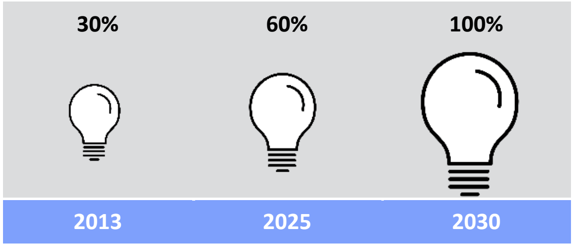


Figure 3: Target dates for access to electricity

Despite adequate capacity in urban and business areas, power outages are common, with businesses and households relying on generators as backup supplies. Damaged power plants and transmission lines, a shortage of spares, illegal connections and lack of skills contribute to this situation. Technical and commercial losses are estimated to be as high as 50%. Non-payment is also a challenge, as approximately 80% of existing electricity consumers are unmetered.

To achieve the electrification targets set in the SET4ALL strategy, it was decided to restructure the National Electricity Company (ENE-EP). Presidential Decree No. 305/14 defined three new companies, namely the Public Electricity Generation Company (PRODEL-EP), the National Electricity Transport Company (RNT-EP) and the National Electricity Distribution Company (ENDE-EP). ENDE is in the process of installing 1.5 million smart meters in key urban locations and increasing enforcement to eliminate illegal connections.

Just over half of the electricity is generated from fossil fuels and the balance from hydroelectric plants. To generate sufficient capacity to address the 2025 targets, Angola aims to grow the installed power capacity to 9.9 GW, of which 66% will be generated from hydropower. The plants, ranging from 80 to 1 000 MW, will be built on several rivers. It is important to continue generating power from other sources to ensure adequate capacity in dry years when river flows are low and hydropower production is reduced. There are no IPPs in Angola.

Table 2: Electrification targets

YEAR	2016	2018	2025
Installed generation capacity	2.7 GW	6.3 GW	9.9 GW
Transmission infrastructure	2 500 km	9 750 km	16 350 km
Electrification rate (% of population)	30%	43%	60%

Expanding the electrical network will also increase the capacity for irrigation. The Aldeia Solar programme has also been introduced to provide photovoltaic solar systems in rural areas not covered by the main grid.

There are three separate transmission grids in the north, central and southern regions. There are plans to link the grids through a north-central-south backbone and expand the grid from 3 354 km to 16 350 km by 2025. All these impressive electrification targets are shown in Table 2.

Gas

Angola is Africa's second-largest producer of natural gas. Angola Liquefied Natural Gas (LNG) has built the world's most modern LNG processing facilities, which are fuelled by gas from a range of sources.

Given the historical reliance on foreign skills, a policy referred to as 'Angolanisation' has been initiated in the oil and gas sector. The policy dictates that 70% of the workforce in any company employing more than five workers must be Angolan nationals, in a bid to build a skilled local workforce through knowledge transfer.

Oil

Current estimates show that Angola has 9.5 billion barrels of proven oil reserves and 11 trillion cubic feet of natural gas. Almost 75% of the oil comes from off-shore fields, which are divided into 50 blocks.

Sonangol is a parastatal that oversees petroleum and natural gas production. It has a stake in 37 oil concessions; 11 are in production and 26 are at the exploration stage. Production costs are high and it is estimated that without new investment in mature fields, production will decline significantly by 2030.

To date, the downstream sector, i.e. refining of crude oil and distribution of products derived from crude oil, accounts for only 20% of the domestic demand. The single oil refinery in Luanda produces 45 000 barrels per day. Capacity will be increased with the construction of the Namibe Refinery and further refineries planned by Sonangol. It is acknowledged that to guarantee continued operation of the infrastructure, young people must be trained in the fields of engineering and technology relating to the petrochemical industry.

Angolanisation in the oil sector requires that for every barrel of oil produced, 15 US cents (US$0.15) must be earmarked for human resource development. Initially introduced in decree 20/82, the requirements were updated in decree 17/09.

Of the US$0.15, nine cents go to the Angolan Ministry of Mineral Resources and Petroleum (MIREMPET) and six are used by oil companies for staff training. Of the nine cents that go to MIREMPET, three are for university funding, one going to Universidade Agostinho Neto (UAN), and one to the Catholic University of Angola (UCAN) to develop courses relevant for the petroleum industry. Each oil company must prepare a plan which includes training and skills targets for all staff. This must be submitted to and approved by MIREMPET. It is reported, however, that implementation of these plans has not been enforced.

Water and sanitation

Angola has many major dams, but several in remote areas were developed for hydroelectric schemes. As a result, in 2015 only 44% of the population had access to safe drinking water, made up of 57% of the urban population and 22% of the rural population.

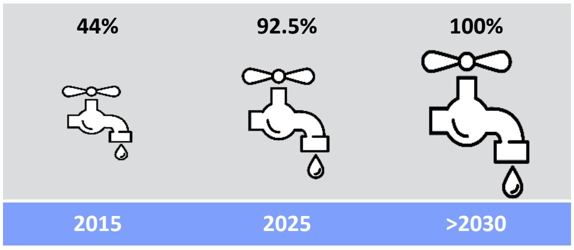


Figure 4: Target dates for access to safe drinking water

Sadly, even the tapped water is contaminated due to broken and ageing pipes, stormwater ingress and lack of sanitation facilities, and is often not compliant with World Health Organization standards as a result of irregular testing and inadequate treatment.

Sanitation also requires attention as in 2015 only 60% of the population had access to improved sanitation, made up of 82% of the urban population and 26% of the rural population.

The National Directorate for Water Supply and Sanitation (DNAAS) under the Ministry of Energy and Water is responsible for water supply, and the National Technical Unit for Sanitation (UNTSA) under the Ministry of the Environment is responsible for sanitation.

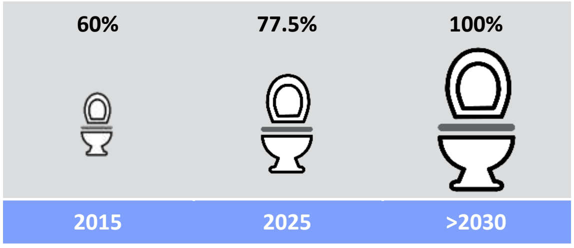


Figure 5: Target dates for access to improved sanitation

Local government is made up of 18 provinces, 164 municipalities and 518 *comunas* (the lowest tier of government), and all have some level of responsibility and authority for water supply and sanitation (WSS) activities. Rural water points are also managed by local government, although community groups are increasingly expected to assume this role.

Over 3 000 boreholes countrywide are the chief source of rural water supply, but many are not working due to shortages of spare parts or fuel for pumps. Difficulty accessing rural areas due to dilapidated roads and the slow process with clearing landmines further constrain WSS improvements.

Service delivery is erratic, inefficient and highly subsidised, with no cost-recovery mechanisms in place. Until recently, the WSS remained the least developed in Africa, resulting in Angola having the highest rate of diarrheal disease in the world.

The Water and Public Water Authority of Luanda (EPAL) will develop a Centre for Tele-management and Technology to manage all water treatment plants and control pipelines. As it is considered a Centre of Excellence, young engineers will be employed, and will be trained in Portugal, China and India, to manage the Centre. The goals for 2025 are to:

- Increase access to safe drinking water to 100% of the urban population and 80% of the rural population
- Increase sanitation coverage to 85% of the urban population and 65% of the rural population
- Increase water consumption by 70 and 30 ℓ/per capita/d in urban and rural areas respectively
- Decrease water losses through the network by 25%
- Rehabilitate and expand water-supply systems and wastewater treatment.

Figure 6: The construction of a road in Cuanza Sul which will create opportunities for isolated communities
(Courtesy: GAUFF Engineering Angola)

TRANSPORT AND COMMUNICATION

The PENAMT seeks to develop Angola's national motorway network (RNAA), the national rail network (RFN), the sea port network (RMP) and logistics platforms.

Roads

Angola's road network is 51 429 km of which only 5 349 km was paved in 2013. Significant progress has been made in the construction of new roads and the rehabilitation and maintenance of existing roads. From 2002 to 2012 some US$12.7 billion was spent on roads and bridges, and a further US$22.6 billion will be spent on these from 2013 to 2025.

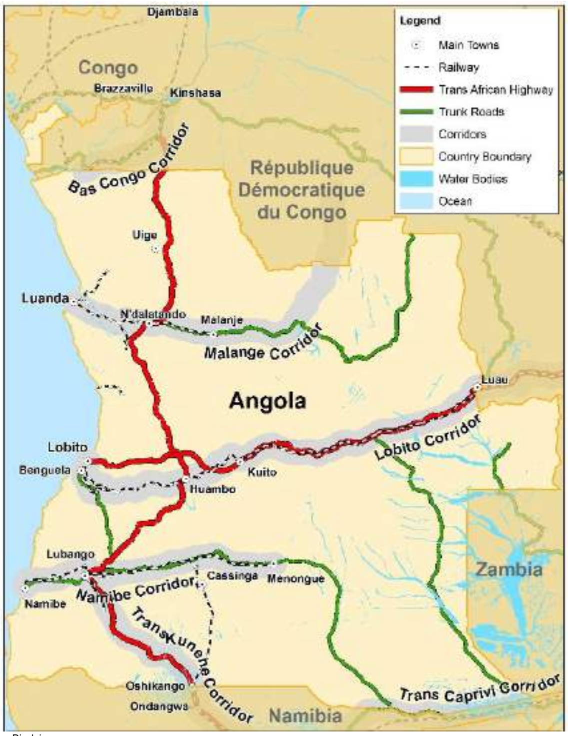
Increased capacity is required to address transport planning to resolve the serious traffic jams and associated road safety challenges nationwide. An update to the National Transport Master Plan has been prepared but capacity is needed to manage the roll-out of the plans, and capacity will also be required to plan and manage maintenance of the much-expanded road network.

Few Angolans own vehicles. They rely on public transport which is limited and in poor condition. Buses and minibuses are being purchased in major centres for urban services and interprovincial travel, but they need to be maintained, and road upgrades need to be prioritised to ensure that such vehicles can serve for their design lives. A Bus Rapid Transit (BRT) system is being implemented in Luanda for which 240 new buses will be purchased.

Rail

There are three main railways traversing east-west, namely the Luanda (425 km), Benguela (1 344 km) and Moçamedes (857 km) Railways, each with their own Board reporting to the Ministry of Transportation. Plans are in place to extend the northern and southern lines eastwards and to build three new lines south to Namibia and north to the DRC and Zambia. These will interconnect with the three east-west lines. A new Congo Railways is also planned, which will link the Luanda Railways line from the Baia Station to the provinces of Uíge, Zaire, and Cabinda. All this represents ambitious plans to build about 5 144 km.

These planned lines, along with the existing track, will require maintenance and capacity to manage the automation controls and signals. To accommodate additional passengers and freight, rolling stock must be substantially increased, along with capacity to maintain the carriages and locomotives. The government plans to promote greater private sector involvement in the rail network and to merge the three railway companies into one and offer their operation to the private sector on a concession basis.



Disclaimer:
Aurecon gives no warranty of any kind, expressed or implied, with regard to the map or data whether for its reliability, accuracy or completeness and shall not be held liable in any event for any loss or damage in connection with or arising out of the use of this data or map. The Client accepts all inherent limitations of the maps and data, including the fact that the maps and data are dynamic and in a constant state of maintenance, correction and revision. The data and map remain the sole property of the CLIENT and may be used for purposes of this Project with the prior written approval from the CLIENT. aurecon

Figure 7: Transport corridors

Ports

The country's ports account for 95% of imports. Although the port of Luanda has been extended, the capacity of the existing ports is still inadequate, hence a new commercial port at Barra do Dande is to be developed and the Port of Lobito is to be rehabilitated and expanded. Another new port, the port of Caio, was first conceptualised in 2007 and when complete in 2019, is projected to increase trade capacity by at least 30%. The port of Namibe, a US$600 million development, will be funded by Japan. Associated with port developments are the development of storage facilities, road and rail corridors and transport hubs.

Airports

There are 31 airports in Angola with paved runways, all of which require significant operations and maintenance capacity. A new airport south of Luanda is being constructed. The national airline Transportes Aéreos de Angola (TAAG) needs to double its fleet to address growing demands. Plans are underway to privatise the airline with the aim of increasing efficiencies, improving service to passengers, raising standards of operability and safety, and reducing operational costs.

Communications

The National Development Plan aims to develop Next Generation Networks (NGN) throughout the country, universal access to telephony services, internet and digital broadcasting. As of 2016, there were 13 million mobile subscriptions, representing a 45% penetration rate. Only 13% of the population was connected to the internet, with less than 1% making use of fixed-line broadband. There are three mobile providers, Angola Telecom, which is state owned, Unitel SA and Movicel Telecomunicacoes Lda, which are privately owned. A fourth provider is being introduced to increase options and competition, and hopefully lower prices.

Connectivity has been enhanced with the laying of submarine cables linking Portugal to southern Africa through the SAT3, South Africa to the Far East through SAFE, the West Coast of Africa to Europe through the WACS cable system and the Angola Domestic Network System (ADONES), consisting of 1 800 km of fibre-optic submarine cable linking eight Angolan coastal cities. Other major developments have included:

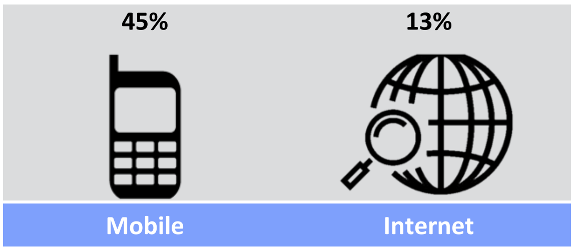


Figure 8: Percentage of population connected to services

- The installation of approximately 25 000 km of national fibre optic network, with the help of public and private investments
- The submarine cable project connecting Angola to Brazil, i.e. the South Atlantic Cable System (SACS) and participation in the Brazil-to-USA Submarine Cable System (MONET)
- The construction of a technology park
- The construction of the first national communications satellite (Angosat) as part of the 2025 Space Strategy Programme.
- The migration from analog television to digital terrestrial television aligned with the Digital Video Broadcasting – Second Generation Terrestrial (DVBT2) standards
- The construction of a network of 25 media libraries throughout the country.

It was intended that Angosat would remain in orbit for 18 years and would provide communications, business intelligence and opportunities to remote areas. Sadly, soon after its launch, communications were lost, and the satellite has become inoperable. Angola plans the development of Angosat-2 to '*cover the whole territory of Angola, Africa and parts of Europe*'.

ICT must be seen as an enabler in all areas of service delivery, including eHealth, eGovernment, eAgriculture, eEnvironment, eEducation and eInfrastructure. This requires a multidisciplinary approach, including thematic experts, computer scientists and systems engineers.

CONSTRUCTION

Construction is important in any country due to its ability to create jobs and develop skills. Since 2002 the construction industry has seen significant growth as Angola has redeveloped damaged or destroyed infrastructure and developed substantial highways and rail lines. Other major developments have included housing projects and associated services, dams, airports, port upgrades, hospitals, schools and universities. Engineering capacity will be required for ongoing operations and maintenance of all this new infrastructure.

Table 3: Major projects identified, or being planned or under construction

PROJECT		VALUE US$	START YEAR	END YEAR
Energy	Angola-Namibia Interconnector	Feasibility stage		
	Caculo Cabaça hydroelectric plant (2 172 MW)	$4.5bn	2017	~2024
	The Laúca Dam and hydroelectric scheme (2 000 MW)	$3.6bn	2012	2018
Water	Build integrated infrastructure in the city of Sumbe, to improve the basic sanitation and urban fabric of the city	$459m	2017	
	Kunene Transboundary Water Supply and Sanitation Project between Angola and Namibia		2018	
Airports	International Airport of Luanda	$3.8bn	2014	2018
	Upgrade and modernise the Maria Mambo Café de Cabinda Airport	$185m	2016	2018
Ports	Port of Barro do Dande	$1.5bn		
	Port of Caio		2015	2019
	Port of Namibe upgrade	$600m	2019	
Roads	Repair three sections of road in the provinces of Cuanza Sul, Cuanza Norte and Malanje	$163.5m	2016	
Other	Construction of the second phase of the city of Kilamba Kiaxi, 30 km from the capital Luanda	$600m	2017	

Sadly, most construction work has been carried out by major foreign companies, mainly from Portugal, Brazil and China. Angola's small construction companies struggle to compete as they have limited access to materials and machinery, most of which are imported. The most significant player in Angola's construction boom has been China which has provided US$13 billion in 'oil-for-infrastructure loans'. The China International Trust and Investment Corporation, Oderbrecht from Brazil and Somague and Mota-Engil, both Portuguese companies, have handled a substantial portion of development.

Although there is legislation requiring partnering with local companies, US$28 billion spent between 2002 and 2015 is unaccounted for and many projects of poor quality have been delivered, either because of a lack of oversight or corruption. Regulations requiring local participation in reconstruction projects were almost never enforced. The lack of local construction expertise, particularly in the public sector, is a problem in terms of supervising construction projects to ensure quality of delivery.

Some of the major projects planned or under construction are listed in Table 3.

Housing

The Sustainable Development Goals 2030 call for access to safe and affordable housing and a reduction in the proportion of the urban population living in slums or informal settlements. Housing development is possibly the biggest of all challenges due to the millions living in unsatisfactory conditions.

Despite the ambitious plans announced in 2008 to build a million houses by 2012, the deficit was more than 1.2 million units in 2015, with 90% of the urban population still living in inappropriate conditions. To address these conditions, housing and infrastructure, including water and sewerage networks, treatment processes, roads, electricity, and social facilities such as schools, hospitals and community areas must be developed.

Sadly, the planning for the first million houses did not take local conditions and the African lifestyle into account. The first development was located 50 km from Luanda, isolating people from job opportunities, and was composed of five- to eleven-story blocks of flats, which did not appeal to the locals at all and have become 'Dormitory Towns'. The African lifestyle is community based, and extended families are used to having space and socialising at ground level. In addition, logistics such as lifts and air-conditioning require electricity, a commodity still affected by regular outages. The orientation of buildings facing east and west also increased the heat.

Ideally, mixed land use locating labour in close proximity to industrial areas is essential to limit travel time and costs and to ensure that families can spend time together. The pricing, too, ended up being way beyond the means of low-income earners, defeating the object of the development in the first place. Designs prepared offshore, as was the case with these units, should be checked and approved by local consultants and the client Ministry for local suitability and acceptance before any development commences.

LOCAL GOVERNMENT

While the utilities provide electricity, water and regional roads, municipalities are expected to develop and manage wastewater treatment works, urban roads and associated stormwater, street and traffic lights, municipal amenities, emergency services and cemeteries, among others. Without delivering fee-earning consumer services, municipalities rely on rates from a small rate-paying population, which is inadequate to cover development, operations and maintenance. Engineers are only to be found in the largest municipalities. To improve local services, there are plans to devolve the end-user delivery of water and electricity to local government, by around 2020.

Setting up and resourcing structures will be a huge undertaking and assigning staff from central structures was expected to begin by the end of 2018. Care will need to be taken not to disrupt the existing, though limited, services currently provided by the provincial and national structures while setting up the new model.

Due to the low rates and tariffs charged, income and budgets are limited. A change in policy, the installation of prepaid meters for water and electricity, and the enforcement of payment for other services will be required if local government service provision is to succeed.

EDUCATION, TRAINING AND PROFESSIONAL DEVELOPMENT

Education and training is a vital part of developing engineering capacity. All elements, from teaching appropriate subjects at school, to continuing professional development (CPD) need to be in place to educate, train and ensure that engineering personnel remain abreast of the latest technology, challenges and emerging solutions.

A generation of Angolans have missed out on education and the government is engaged in a daunting struggle to reintegrate them into society. It is estimated that 48% of the adult population never attended school.

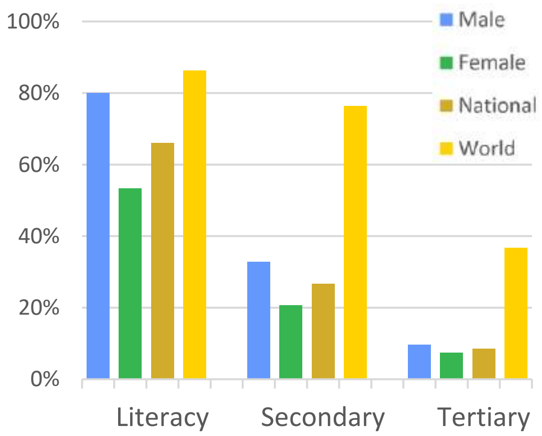


Figure 9: Literacy and enrolment statistics
(UNESCO from 2011 to 2015)

PRIMARY AND SECONDARY EDUCATION

Primary education is compulsory, free at public schools and lasts for six years. The shortage of schools and teachers, however, makes it difficult to enforce universal primary school attendance.

Secondary education is composed of the first cycle, Grades 7 to 9, and the second cycle, Grades 10 to 12. Considering Census 2014, it can be seen that dropout rates throughout secondary education are very high, with 18% dropping out in Grade 7, reducing to 16% in Grade 10 and so on, with the result that the number completing Grade 12 is relatively low.

Access to higher education is possible after Grade 12. Sadly, the standard of teaching is such that many school leavers are unable to solve even basic mathematics problems, and some are even illiterate.

VOCATIONAL TRAINING

Learners may leave school after Grade 9. Those continuing may complete general second-cycle education for three years or may follow a four-year technical/vocational course at one of the 196 technical schools, to receive what is termed a mid-level qualification (after year 13). Vocational training falls under the National Institute for Employment and Vocational Training (INEFOP).

There are currently no qualifications offered which are equivalent to the three-year higher education technician diplomas in neighbouring countries. These were offered through polytechnics prior to independence. Learners now either become mid-level engineers or continue with higher education to become engineers.

HIGHER EDUCATION

Agostinho Neto University, a public university, is the oldest university, established in 1962. Until 2009, it was the only public university but had campuses in the major centres. As a result of the drive to reform education and make it accessible to all, in 2009 the campuses broke away from the university to become independent regional universities. These offer five-year engineering degrees from which students graduate with a licentiate and are known as engineers.

Polytechnics known as Instituto Superior Politécnico offered four-year, more practical qualifications whose graduates were known as technical engineers. In recent years the content of both qualifications has moved closer together and graduates from both streams are known as engineers, whether completing four or five ye ars of study.

By 2015 there were 18 universities, 10 of which are private, 40 higher education institutes, 30 of which are private, and four higher schools, which are state owned. This has taken the number in higher education from approximately 500 in 1962 to 241 284 in 2015. The list of new universities offering engineering qualifications, from which there had not been graduations in 2015, is shown in Table 4.

With the limited number of high-calibre school leavers, many entering universities fail the entrance exam but are nevertheless admitted. These students struggle with their studies and drop out. There is a need to offer bridging support to weak students entering higher education as there are insufficient numbers enrolling for engineering courses, considering the size of the country and the development required.

There are over 30 institutions offering engineering education, and some 100 qualifications on offer, against only about 1 000 graduating per year. This means that very few institutions or faculties would earn sufficient income to be adequately resourced.

Table 4: Universities in which engineering students were enrolled in 2015 but had not yet graduated

INSTITUTION
Public institutions
Universidade Onze de Novembro (Cabinda)
Private institutions
Instituto Superior Politécnico Metropolitano (Luanda)
Instituto Superior Politécnico Katangoji (Luanda)
Instituto Superior Politécnico de Tecnologia e Ciências (Luanda)
Instituto Superior Politécnico Internacional de Angola (Luanda)
Instituto Superior Politécnico de Kangojo (Luanda)
Instituto Superior de Tecnología de Informação e Comunicação (Luanda)
Instituto Superior Politécnico de Porto Amboim (Cuanza-Sul)
Instituto Superior Politécnico de Benguela (Cuanza-Sul)
Instituto Superior Politécnico Católico de Benguela (Cuanza-Sul)
Instituto Superior Politécnico Maravilha (Cuanza-Sul)
Instituto Superior Politécnico Lusíada do Huambo (Huambo)

Assessments indicate that there is a lack of laboratory facilities and equipment, limited reference material, and curricula that need to be reviewed and harmonised. Given the increase in the number of institutions, there is an acute shortage of lecturers, and lecturers are asked to double up and serve both the public and private institutions.

There are also those who are not up to date and many have not been trained on how to deliver courses in higher education. Given the fact that each discipline requires specialists in a number of subdisciplines, the limited numbers mean that lecturers may not have the knowledge or experience in some of the subjects that they must cover. It appears that rationalisation of the offerings will be necessary to improve the standard.

The Department of Higher Education under the Ministry of Higher Education, Science, Technology and Innovation (MESCTI) has put much effort into collecting graduation data since 2013 to understand how the sector has expanded. The data provided by UAN does not quite match the data published by the MESCTI, but the figures are close. The institutions from which there were engineering graduates in 2015 are shown in Table 5.

Reports of students having to pay staff to progress are of concern, as is the notion that professors are required to pass 80% of their students. Academic salaries are said to be very low, resulting in lecturers taking second jobs, limiting the time they spend on their academic responsibilities. A further challenge is the limited number of post-graduate students, which limits the capacity to carry out research, develop future academics or develop specialists and innovators for industry.

The only graduation data available for the full period under review was from the Universidade Agostinho Neto which has seen a steady increase in graduations, as shown in Figure 10. Figure 11 shows graduation trends from all institutions per discipline, category and gender over a shorter period.

Accreditation

The MECSTI are concerned with the number of institutions that have sprung up which are not accredited and warn students to select only accredited institutions and programmes. The MECSTI has set up the National Institute for the Evaluation, Accreditation and Recognition of Higher Education Studies (INAAREES) whose mission is to promote and monitor the quality of the technical-pedagogical, scientific and services provided by higher education institutions.

Table 5: Engineering graduations in Angola in 2015 as per MECSTI data

INSTITUTION	Agriculture	Chemical	Civil	Electrical & Electronics	Environmental	ICT	Mechanical	Mining & Metallurgy	Petroleum	Telecommuni-cations
Public institutions										
Instituto Superior Politécnico de Benguela – UKB						1				
Universidade Agostinho Neto – UAN (Luanda)			12	34		7	26	21		16
Universidade Cuito Cuanavale (Menongue)	15									
Universidade José Eduardo dos Santos (Huambo)	80					58				53
Universidade Katyavala Buila (Benguela)										
Universidade Kimpa Vita (Uige)						16				
Universidade Mandume YaNdemufayo (Huila)				17	18		22			
Private institutions										
Instituto Superior Politécnico da Tundavala (Huila)	2		4		8					
Instituto Superior Politécnico de Cabinda						41				
Instituto Superior Politécnico de Humanidades e Tecnologias EKUIKUI II						4				
Instituto Superior Politécnico do Cuanza Sul	12									
Instituto Superior Politécnico Independente						12				
Instituto Superior Politécnico Jean Piaget de Benguela		3	5			5	3			
Instituto Superior Politécnico Lusíada de Benguela						3				
Instituto Superior Politécnico Metropolitano de Angola			10							
Instituto Superior Técnico de Angola (Luanda)				12		20	12			14
Universidade Católica de Angola (Luanda)						13				16
Universidade de Belas (Luanda)						3			8	
Universidade Gregório Semedo (Luanda)						27				
Universidade Independente de Angola (Luanda)			2		7	19				9
Universidade Jean Piaget de Angola (Luanda)							23		22	
Universidade Lueji A Nkonde (Dundo)							31	28		
Universidade Lusíada de Angola						66				
Universidade Metodista de Angola (Luanda)			33	16		16	36			
Universidade Óscar Ribas (Luanda)			10			26	10			
Universidade Privada de Angola (Luanda)			14			62				
Universidade Técnica de Angola (Luanda)					25	99		4		
TOTAL										
Engineers from universities (1 020)	95		71	67	50	412	148	53	30	94
Engineers from ISPs (171)	14	3	19	12	8	86	15	0	0	14

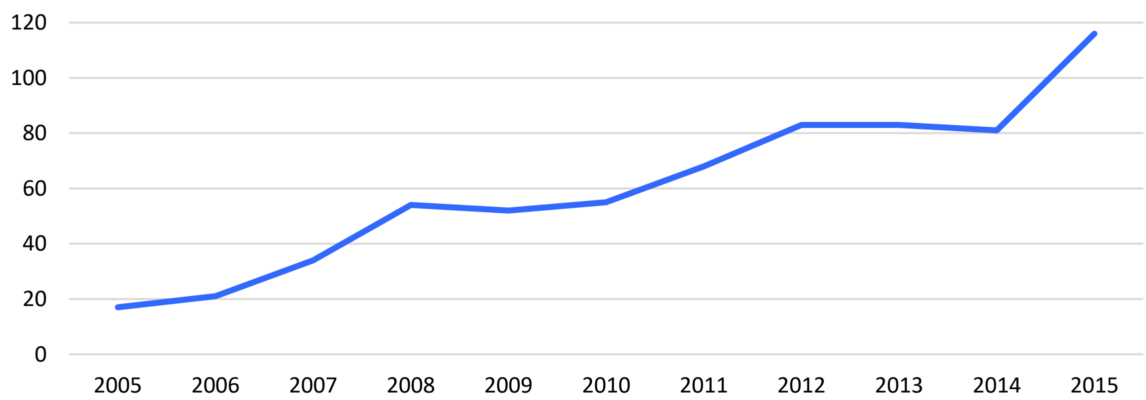


Figure 10: Engineering graduations from the Universidade Agostinho Neto using UAN data

Figure 11: Engineering graduates by discipline, category and gender using MECSTI data

As many subjects in engineering qualifications are common across disciplines, it is more cost-effective for an institution to offer a range of engineering qualifications to harness all engineering academics and share facilities.

In setting up a framework for accrediting engineering qualifications, guidelines from the Washington Accord or from the European Network for Accreditation of Engineering Education (ENAEE) should be used to develop a robust process.

Accreditation teams should be composed of experienced engineering professionals sourced from the OEA and senior academics with a comprehensive understanding of the needs of the country and the rigours of the Accords.

At present, the public and private institutions are offering different content, structure and duration (public five years and private four years) for the same qualification. Alignment is required.

Student mobility

In 2015, there were 1 100 Angolans studying at South African universities, of whom 278 were studying by correspondence through the University of South Africa.

A total of 52 graduated with engineering qualifications – 13 completing BTechs and 39 with national diplomas. Almost half of the graduates studied at the Cape Peninsula University of Technology.

Large numbers of Angolan engineers have studied outside the country over the years, the most popular countries being Portugal, Brazil, South Africa, the USA and Cuba. In the past few years, many students have studied in China. Before commencing their studies, they have had to spend a year learning Chinese, which is generally insufficient to be able to grasp the complex concepts taught in engineering courses and few have successfully developed sufficient engineering knowledge to contribute as engineers when back in the Angolan workplace. The value of employing such graduates is their ability to act as interpreters between local consultants and project oversight staff and Chinese contractors.

GRADUATE TRAINING

Companies complain that graduates can do nothing when they arrive in the workplace. This is to be expected as tertiary education concentrates on theory. It is necessary for graduates to get structured training in the workplace, under professional supervision and mentorship, to develop to the level of competence to be able to take on work independently. Apart from structured training being offered by a few of the larger consulting practices and public sector structures, little support is offered in the training of graduates. This is contrary to the spirit of Angolanisation; the requirement for structured training should be defined and enforced on all public-sector projects.

PROFESSIONAL REGISTRATION

There are two organisations that register engineering practitioners in Angola, the Ordem dos Engenheiros de Angola (OEA), which registers engineers and technical engineers, and the Associação Profissional Engenheiros Técnicos Angola (APET), which registers only technical engineers.

In November 2018 there were 3 843 professionals registered by the OEA, distributed per discipline as shown in Table 6. The are several categories of registration as follows:

- **Efectivo (E1):** engineers with 20+ years of experience
- **Efectivo (E2):** engineers with 10+ years of experience
- **Efectivo (E3):** recently graduated engineers
- **Associado (A1):** technical engineers with 20+ years of experience
- **Associado (A2):** technical engineers with 10+ years of experience
- **Associado (A3):** recently graduated technical engineers
- **Associado Júnior (Estagiário):** final year student members.

There are some 2 000 juniors who have applied for membership, but having studied in Angola and abroad, await accreditation of their qualifications, which is a lengthy process. Those whose qualifications had a strong theoretical and problem-solving base will be registered as graduate engineers, while those who have followed more practical and engineering management curricula will be registered as graduate technical engineers. Students are not included in Table 6.

Other categories of recognition include honorary members (seniors), specialists in the fields related to engineering but who do not have an engineering qualification, and council members.

The OEA was established in 1992 through Decree Nº. 39-E/92 to promote professionalism and quality in engineering work. It is expected to engage at all levels to ensure the well-being of society and the development of Angola. Its role includes increasing the visibility of the engineering profession and addressing the interests and development needs of all engineers.

The OEA performs roles typical of both a registering body and a voluntary association in that it not only registers engineers and monitors performance, but also organises conference, workshops, think-tanks and offers training, career development and advisory services to both the public and private sectors. It has a very comprehensive strategy to deliver on its mandate.

It is estimated that about 35% of all engineers in Angola are registered with the OEA and they are on drive to increase this number. The approach to registration by the OEA is different from that adopted in other SADC countries in that registration is conferred on those that have graduated with a

Table 6: Registration with the OEA by discipline and category, November 2018

SECTOR	Efectivo E1	Efectivo E2	Efectivo E3	Associado A1	Associado A2	Associado A3	Councillor	Extraordinary	Senior
Agricultural	192	10	11	3	0	0	0	0	12
Chemical	143	0	4	1	1	0	1	1	1
Civil	1 534	66	254	56	7	8	13	3	30
Electrical & ICT	532	9	135	19	6	3	2	3	1
Geographical	103	1	12	6	0	1	0	0	1
Mechanical	280	4	61	11	1	1	3	1	28
Mining & Petroleum	241	4	14	5	0	2	1	0	1
TOTAL	**3 025**	**94**	**491**	**101**	**15**	**15**	**20**	**8**	**74**

recognised engineering qualification. There are plans to introduce professional registration of those who have become competent in the workplace and are able to develop complex engineering solutions independently. This will align with the International Engineering Alliance (IEA) approach.

In February 2015 APET was launched. This is similar to the Portuguese Ordem dos Engenheiros Técnicos (OET), i.e. the Order of Technical Engineers. It was established to offer technical engineers working in Angola a professional home.

Although bachelor qualifications were offered in Angola years ago, they have only recently been reintroduced. Technical engineers are widely used in construction and project management and are found overseeing public sector projects. Most technical engineers have studied in Portugal and countries such as Russia, Cuba, the Far East and Eastern Bloc countries. Recognition of professional qualifications and the conditions for the registration of technical engineers in each country has been established by the OET to allow the movement of professionals.

In April 2018, there were 250 technical engineers registered with APET. It is thought that this represented 25% of the technical engineers in the country.

Given the similarity in vision between the two organisations and the services they offer, cross-accreditation negotiations are underway which should be supported in the interests of all members.

VOLUNTARY ASSOCIATIONS AND CONTINUING PROFESSIONAL DEVELOPMENT (CPD)

Once they have been registered and are practising, it is important for professionals to continue with their development to keep pace with the latest technology, research, alternative solutions, standards and legislation. Various training houses, higher education institutions and the OEA are active in this field. The OEA offers a range of courses and workshops, and hosts conferences and think tanks to address burning issues, although it does not have an official CPD policy. Once professional registration is in place, CPD should become a requirement for retaining professional registration.

WOMEN IN ENGINEERING

The is no dedicated Women in Engineering structure in Angola, but many initiatives have been put in place to encourage more women to enter the profession. FormPRO has launched an initiative to encourage women to enter the construction sector and Power Africa encourages women to enter the field of electrical engineering.

THE WORKFORCE

Based on the above discussion, it is estimated that there are approximately 9 000 engineers in Angola, including technical engineers. An indication of the age and gender distribution based on OEA membership is shown in Figure 12. The characteristic 'hole in the middle', in this case of those in their early 50s, indicates the disruption of studies during the years of the civil war.

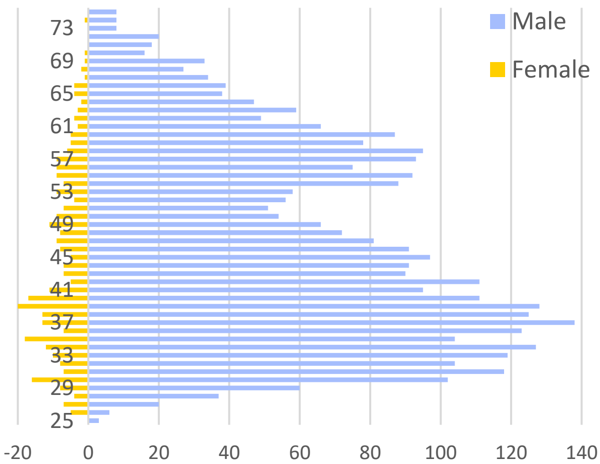


Figure 12: Membership of the OEA by age and gender, 2018

THE PRIVATE SECTOR

The main employers in the private sector are consulting, contracting, manufacturing, supplier and mining companies. Lower numbers are employed in small entrepreneurial companies, training organisations and those where engineering input is required, as well as NGOs assisting with social infrastructure, rural development and enhancing farming methods.

Consulting and contracting

There are several organisations representing the interests of the construction sector. The Association of Building Materials Industries of Angola (AIMCA) is one such body which was set up in 2015 to promote member products to customers, best practice and to ensure the quality of products for sustainable construction. It recently hosted its first seminar on Construction Materials in Angola.

Another body, the Angolan Contractors of Civil Engineering and Public Works Association (AECCOPA), was formed in 1998 to represent the interests of members and partners and to support sustainable development. It has around 250 members, including small, medium and large companies. The training of upper middle technicians is one of its objectives to address the shortage of civil construction specialists. The challenge of poor supervision was highlighted by the previous Uíge Governor Paulo Pombolo when he said '… *rigorous supervision of works'* should be put in place to ensure *'… a greater durability and quality'.*

There is also the Association of Real Estate Professionals of Angola (APIMA) which offers services covering legal, tax, financial, technical, ethical and social information to its members.

Since 2015, the registration of consultants and contractors has been the responsibility of the Regulatory Institute for Civil Construction and Public Works (IRCCOP) under the Ministry of Construction. Presidential Decrees Nos 63/16 and 106/14 of 2016 and 2014 respectively outline the requirements, including the need for a registration certificate and a permit. Applicants for registration must be in good standing and must show that they have insurance to cover accidents on projects for all employees.

To be eligible for permits, companies must meet technical, economic and financial requirements, and must specify their technical capacity, including qualifications. They must also provide details of their office, their range of plant and equipment and past experience. Three types of permits are issued – a Civil Construction and Public Works Permit, a Works Design and Planning Permit and a Works Supervision Permit.

Whereas registration certificates are valid for 10 years, permits are valid for a period of only three years. Permits are classified according to the category and class, depending on the value of the works. When companies do not have staff with the required qualifications, they may subcontract to those who have approvals. In these cases, the company must enter into a valid contract with the subcontractor.

The IRCCOP is responsible for ensuring compliance. Any infringements may lead to suspension or cancellation of the activity, fines or prohibitions. The IRCCOP is expected to create and maintain a database of companies to evaluate their performance.

There are some 30 consulting engineering companies, the larger ones of which are branch offices of international consulting firms. At the end of 2018, there were 1 812 contractors registered with the IRCCOP, 170 of which were in the largest grade, able to handle any size of project. As with consultants, the largest contractors are foreign or subsidiaries of foreign companies, with Brazilian-owned Odebrecht being the largest employer in Angola. It is estimated that around 1 000 engineers are employed in the sector supported by significant numbers of mid-level engineers. This might, however, be understated as low numbers of engineers from Asia register with the OEA.

Manufacturing

There were 2 000 manufacturing companies in 2000, employing 3 000 people. Manufacturing has grown considerably since the end of the civil war, with Angola now having the third-largest manufacturing sector in the SADC region. Considering the substantial petrochemical industry, beverage production and growing subsectors as described under *Engineering Activities*, it is estimated that around 1 700 engineers are employed in the sector along with teams of mid-level engineers.

The Industrial Technology and Innovation Centre (INITI) and the Association of Industrialists of Angola (AIA), both falling under the Ministry of Industry, represent the interests of the manufacturing sector. They support the development of new products, certify all products to ensure maintenance of standards and devote much time and energy to attracting investment.

Mining

Over the years, the Oil Ministry has developed an impressive model to ensure skills development in their sector, which was described under the section titled *Oil*. Since all companies in the sector have access to the training fund collected against the production of oil, they are obliged to prepare skills development plans and report on all their staff annually.

Information on engineering skills is therefore available and is updated annually. Since the merger of the Ministry of Oil with the Ministry of Mines, mining companies have also been encouraged to develop training plans and submit their skills reports to the ministry.

It is estimated that around 1 000 to 1 500 engineers are employed in the mining sector outside of government.

THE PUBLIC SECTOR

Many engineering practitioners are employed in the public sector, particularly in the state-owned entities which deliver energy, water and transport services, as shown in Table 7. Based on returns from infrastructure ministries, it is estimated that around 3 000 to 3 500 engineers are employed in the public sector.

Some structures reported high vacancy levels, citing low salaries as part of the challenge to attract engineering skills. Angola has realised the need to increase the remuneration of teaching staff in order to attract and retain high-calibre teachers. A similar initiative to consider salary levels commensurate with qualifications and level of responsibility for engineering staff should also be embarked on. Utilities advise that the control of tariffs is limiting their income, thus limiting the budget available for staff.

It was announced in mid-2018 that Angola plans to privatise 74 state-owned companies over the next few years in order to reduce government interference and attract private sector finance. It is hoped that this will in some way improve services and pave the way for engineers to be used more effectively in their structures.

Table 7: Ministries employing engineering practitioners

MINISTRY/STRUCTURE
Ministry of Agriculture and Forestry – Ministério da Agricultura e Florestas
Ministry of Construction and Public Works – MINCOP
Ministry of Energy and Water – MINEA (Ministério da Energia e Águas) • Public Electricity Generation Company – PRODEL-EP (Empresa Pública de Produção de Electricidade) • National Electricity Transmission Company – RNT-EP (Empresa Nacional de Transporte de Electricidade) • National Electricity Distribution Company – ENDE-EP (Empresa Nacional de Distribuição de Electricidade) • Regulatory Institute of the Electricity Sector – IRSE (Instituto Regulador do Sector Eléctrico) • Electricity Supply Company – EDEL (Empresa de Distribuição de Luanda) • National Institute for Rural Electrification • National Directorate for Water Supply and Sanitation – DNAAS (Direcção Nacional de Abastecimento de Água e Saneamento) • Public Water Company (per province) • National Water and Sanitation Company (per province) – EAS (Empresas Nacional de Água e Saneamento) • Solid Waste and Sanitation Company of Luanda – ELISAL (Empresa de Limpeza e Saneamento de Luanda) • Operational Office of Médio Kwanza – GAMEK (Gabinete de Aproveitamento do Médio Kwanza) • National Institute of Water Resources – INRH (Instituto Nacional de Recursos Hídricos) • Office for the Administration of the Cunene Hydroelectric Basin – GABHIC (Gabinete para a Administração da Bacia Hidrográfica do Rio Cunene)
Ministry for Fisheries and Sea - Ministério das Pescas e do Mar
Ministry of Environment – MINAMB (Ministério do Ambiente) • National Technical Unit for Sanitation – UTNSA (Unidade Technica Nacional para Saneamento)
Ministry of Industry – Ministério da Indústria • Industrial Associationof Angola – AIA (Associação Industrial de Angola)
Ministry of Commerce –Ministério do Comércio
Ministry of Economy and Planning – Ministério da Economiae Planeamento
Ministry of National Defence – Ministério da Defesa Nacional
Ministry of Mineral Resources and Oil – MIREMPET (Ministério dos Recursos Minerais e Petróleos) • National Petroleum Company– Sonangol (Sociedade Nacional de Combustíveis de Angola)
Ministry of Land/Territory Administration and Government Reform – MATRE (Ministério da Administração do Território e Reforma do Estado), which covers all provinces, districts, municipalities and communes
Ministry for Spatial Planning and Housing – Ministério do Ordenamento do Território e Habitação
Ministry of Telecommunications and Information Technologies – Ministério das Telecomunicações e Tecnologias de Informação • Angola Telecom
Ministry of Transport– Ministério do Transporte • National Institute of Civil Aviation – INAC (Instituto Nacional de Aviação Civil) • National Company of Airport Development and Air Navigation – ENANA (Nacional de Exploração de Aeroportos e Navegação Aérea) • National Directorate of Transport– Direcção Nacional dos Transportes • Transport of Luanda – TCUL (Transportes Colectivos Urbano de Luanda) • Angolan Air Transport– TAAG (Transportadora Aérea Angolana) • National Institute for Railways in Angola – INCFA (Instituto Nacional dos Caminhos de Ferro de Angola) • Institute for Ports in Angola – MPA (Instituto Maritimo e Portuario de Angola)
Ministry of Higher Education, Science, Technology and Innovation – Ministério do Ensino Superior, Ciência, Tecnologia e Inovação • National Centre for Scientific Research – CTN (Centro Nacional de Investigação Científica)

Table 7: Ministries employing engineering practitioners

MIGRATION TRENDS

Analysis of the United Nations Population Division statistics for 2015 shows a net loss of professionals from Angola. Of those entering the country, 32% were from the DRC, 7% from Cape Verde and 6% from Sao Tome and Principe. Fifty-five per cent of professional emigrants moved to the Congo, 24% to South Africa and a further 17% to Portugal. Some

18% of professionals registered with the OEA are expatriates, the majority of whom are from Portugal, while smaller numbers come from Brazil, Cuba and other countries, as seen in Figure 13.

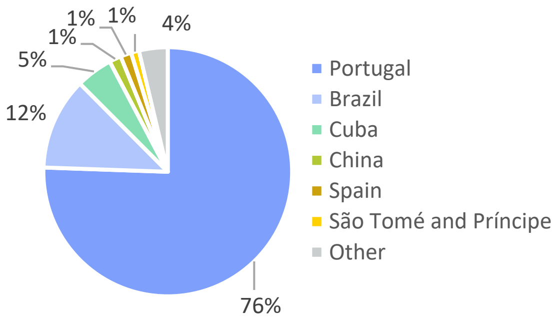


Figure 13: Nationalities of foreign engineering practitioners registered with the OEA

These figures refer only to those who officially emigrated or immigrated. There is ongoing movement of engineering professionals as projects are awarded to international companies. Significant numbers of Chinese, Portuguese, Brazilian and Korean engineers working on construction projects move in and out of the country, without registering with the OEA, since they are not responsible for the design phase of projects.

ENGINEERING NUMBERS AND NEEDS

Considering all the engineering developments in recent years, engineers have clearly played a key role in the development of the Angolan economy. However, considering all the developments planned, it is evident that more qualified and well-experienced engineers will be needed. Projections are based on there being some 9 000 engineers and technical engineers in the workforce.

Currently some 1 200 engineers graduate in Angola per year, made up of 1 020 from universities and 170 from ISPs. Once graduates from new institutions start to graduate from the end of 2019, the number will increase. The number available to enter industry each year is also augmented by returning graduates who studied outside the country.

In interpreting the MECSTI data, there is a concern that the hundreds listed under engineering informatics and information management have in fact received scientific rather than engineering training, hence the number of engineers used in the projections below have been reduced to 850 engineers graduating and 150 new graduates per year from 2020, as there was little evidence of substantial numbers of systems and software engineers in returns from engineering organisations, except in telecommunications.

Figure 14 shows the current numbers, the losses that will occur over the 18-year period to 2035 due to retirement, mobility and mortality, and the growth of engineering capacity if the graduation rates increase by 2% per year. The blue dotted line shows the growth in skills that would be required at the 2017 GDP growth rate of - 2.5% and the green dotted line the shows the growth based on the 2018–2023 GDP projection of 2.8%. A 70% employment elasticity factor has been use to extrapolate the employment demand.[*1]

It is suggested that engineering capacity is currently insufficient, and that Angola needs at least 15 000 engineers. The desired numbers will be achieved by 2026 if the demand remains static. However, if the demand increases at 2.8% this will move out to 2029. To achieve the increased numbers commitment will be required to start filling posts immediately and investing in graduates to ensure that they develop the competence required to assist with the workload.

Should large-scale appointments not take place and the 2.8% growth rate continues, the number of graduates will substantially exceed the demand. If Agenda 2063 growth rates can be achieved, the rate of graduation will slightly exceed the demand. The ratio of graduates to experienced personnel will be high and large national, structured and funded workplace training programmes will be necessary.

Given the increasing output trends from each of the new and existing institutions, as evidenced by the Agosthino Neto University trend shown in Figure 10, and the fact that more graduates will emerge from the newer institutions, the increase in graduations will greatly exceed the 2% projection used in the above model. Consideration needs to be given to consolidating engineering qualifications and only offering them in well-resourced institutions.

When determining where to adjust the graduation rates, consideration needs to be given to industry demands. Of concern is the fact that the mix of

[*1] Employment elasticity is a measure of the percentage change in employment associated with a 1% change in economic growth. If the growth is likely to be in agriculture, the percentage could be lower, as growth in that sector generally has to do with productivity gains and not employment, while if the growth is likely to be in high-tech manufacturing, the elasticity factor may be more than 100%.

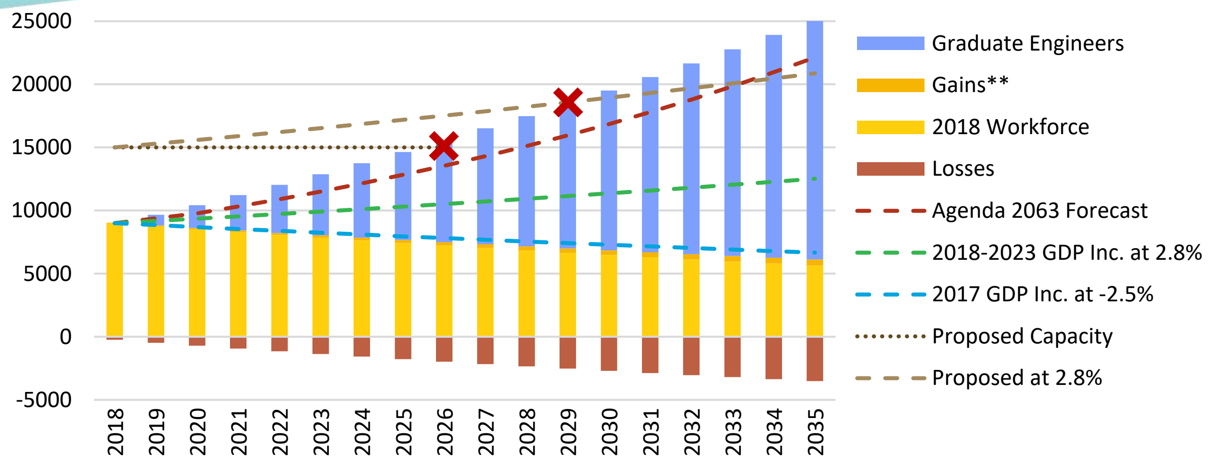


Figure 14: Flow of engineering skills based on a 2% growth in graduation rate per year

***Excludes international engineering practitioners in the country on short-term contracts*

graduates per discipline does not reflect the mix registered with the OEA. A detailed analysis and engagement with industry is required in this regard.

- **Chemical engineering:** The number graduating is very low by comparison with the number of registered chemical engineers in industry. As the economy is largely based on petrochemicals and there is a desire to increase agro-processing, bursaries should be offered to grow the pool.
- **Civil engineering:** A steady flow of civil engineers is required. The number graduating appears to be proportionally much lower than the number registered with the OEA although the number of graduates returning from overseas is unknown.
- **Electrical and electronic engineering:** The number graduating is relatively low. They are needed in generation, transmission, distribution, renewable energy, manufacturing and automation among others.
- **Industrial engineering:** There are few industrial engineering practitioners in Angola. They could play a significant role in improving production and streamlining systems. Consideration needs to be given to developing an industrial engineering qualification, or a postgraduate qualification.
- **Mining and metallurgy:** With plans to develop more mines and handle more processing and beneficiation locally, the requirements of this sector will need to be assessed to determine how to adjust or expand existing programmes.
- **Oil and gas:** Dedicated oil and gas engineering qualifications have only recently been introduced. The Ministry is also opening a school. The qualifications need to be aligned and consideration needs to be given to working with Mozambique to offer qualifications that will cover the needs of both countries.

KEY RECOMMENDATIONS

To develop a sound pool of engineering professionals, able to contribute to the well-being of Angola, the following should be considered:

Schooling

- **Primary and secondary education:** Address the weaknesses in primary and secondary education, and increase the number completing secondary education with acceptable results.
- **Career guidance:** Expand career guidance to attract high-calibre entrants into the engineering profession, incorporating programmes to reach female learners, and rural and low-income areas.
- **Bursaries:** Provide bursaries to attract those with good mathematics and science passes to study engineering.

Higher education

- **Consolidation:** Consolidate engineering studies into well-resourced universities and institutes to ensure quality output.
- **Accreditation:** Develop a rigorous national accreditation programme in collaboration with the OEA and APET to ensure the quality of engineering education using the guidelines of the Washington Accord or alternatively, consider using the accreditation guidelines of the European Network for Accreditation of Engineering Education (ENAEE).
    - Encourage institutions to develop adequate complex engineering problem-solving content and graduate attributes to satisfy the requirements of the Washington Accord.

- Create awareness of accredited qualifications and warn learners of those that will not lead to registration as engineering professionals.
- Withdraw qualifications which do not meet accreditation requirements.

- **Alignment:** Align the qualifications offered by public and private institutions.
- **Industry liaison:** Liaise with industry on a regular basis to ensure that curricula, methods, software and equipment are relevant and up to date.
- **Curricula:** Provide funding to research, modernise or develop curricula and material where required.
- **Facilities:** Raise funding to upgrade lecture theatres, libraries and laboratory facilities where required.
- **Resources:** Raise funding for computers, engineering software, access to online reference material, and laboratory and other equipment, and ensure adequate support to offer technology-relevant training.
- **Attract and retain academics:** Improve conditions of service, support and packages to attract, retain and appoint additional academics.
- **Academic development:** Provide funding for lecturer post-graduate development and facilitate opportunities for academics to gain experience in industry.
- **Chemical and industrial engineering:** Expand the capacity of chemical engineering departments and consider offering an industrial engineering qualification.
- **Oil and gas:** Continue with the development of oil, gas and mining qualifications to match local needs.

Graduate training

- **Develop programmes:** Develop national graduate training programmes to ensure graduates achieve the level of competence required by industry and for professional registration.
- **Private sector incentives:** Offer incentives for private sector companies to develop graduates.
- **Public sector support:** Ensure that public sector structures take on and train graduates and that they are absorbed and developed through the ranks.
- **Institutional support:** Institutionalise graduate training in all organisations by setting KPIs for experienced staff to act as supervisors and mentors.
- **Project support:** Make graduate training a requirement of all public sector projects and ensure that the progress of graduates is monitored, and penalties are imposed for non-compliance.

Registration of engineering professionals

- **Registration:** Support the OAE to develop a rigorous professional registration process to assess competence in the workplace, rather than registering professionals based solely on the achievement of academic qualifications.

Continuing development

- **CPD:** Support the participation of engineering practitioners in CPD activities.
- **Post-graduate studies:** Provide post-graduate bursaries to develop specialists.
- **Develop managers and leaders:** Encourage industry to continue investing in graduates after professional registration to grow management and leadership capabilities.
- **Understudies:** Ensure understudies are assigned to foreign experts in line with the Angolanisation policy.

Registration of service providers

- **Legislation:** MINCOP to consider expanding the construction legislation to:
  - Cover the increasing use of local consultants, contractors, labour, plant and materials.
  - Ensure that foreign consultants and contractors partner with local companies.
  - Ensure that there are requirements for consultants and contractors to train graduates, artisans and other construction-related skills.
  - Ensure that local contractors are developed as part of large projects.
  - Ensure that international consultants provide all calculations, drawings, operating manuals and other reference material in Portuguese.
  - Ensure that local consultants, along with the client, check that design proposals address local needs and customs and that design calculations comply with national codes and standards.
- **Quality:** Implement quality assurance and ensure penalties are imposed for poor performance.
- **Angolanisation**: In line with the Angolanisation policy, ensure that foreign service providers develop local understudies to take over from expatriate experts on completion of their contracts.

The public sector

- **Economic infrastructure:** Invest in the development of economic infrastructure such as electricity, roads, rail, ports and airports, and address the supply of water services.

- **Maintenance:** Invest in maintenance to preserve new infrastructure and prevent further deterioration of existing infrastructure.
- **Tariffs and payment:** Review and increase tariffs where appropriate, enhance domestic revenue collection and demand management to fund development.
- **Technical capacity:** Reprioritise budgets to fill vacancies and build technical capacity, ensure that salaries are competitive and develop succession plans to make the public sector an employer of choice.
- **Technical decision-makers:** Ensure that engineers are employed in senior decision-making posts.

Industry-wide collaboration

- **Advisory team:** Set up an engineering advisory team, recognised by government, to advise on and endorse infrastructure development proposals, tertiary curricula and graduate training programmes.
- **Collaboration:** Encourage all professional bodies to work together to share knowledge, exchange best practice and ensure coordinated planning of industry support initiatives.

ACKNOWLEDGEMENTS

Progress would not have been made in Angola without the assistance of the President of the OEA, Paulino Augusto Neto, the South African Embassy and the Foreign Office who made initial contacts and set up meetings. Special thanks to Mathilde Antonio for the logistics and for following up on the data. Thank you to Eduardo Andre and Dennylson Pinto for participating in meetings, interpretations and providing OEA data and insights. Thank you too, to the many committed engineers in academia and engineering ministries, contracting and consulting firms who prepared data and made contributions.

SOURCES OF INFORMATION

Data and information were gathered during the OEA Conference in 2018, meetings, interviews and telephone conversations, and via email. SADC reports, master plans and strategies as listed under *Plans and Strategies,* and many standard international sets of data as listed in Chapter 5, *Research Approach,* were also consulted. Further information was gathered from newspapers such as *Angola Today,* etc., the Angola Press Agency Portal, several PricewaterhouseCoopers reports, Angola is Now and the government portal. Comprehensive documents focusing on specific issues in Angola as listed below were additional sources of information.

Bednarski, C.M. 2015. *Urbanisation in Africa –Taking Angola as an example*. Paper presented at the IABSE Conference – Structural Engineering: Providing Solutions to Global Challenges, 23–25 September 2015, Geneva, Switzerland.

Carvalho, P. 2012. Evolution and growth of higher education in Angola. *Revista Angolana de Socilogia*, 9: 51–58.

Centro de Estudos e Investigação Cientifica (CEIC) da Universidade Católica de Angola. 2012. *Relatório económico de Angola 2011*. Luanda: CEIC.

Da Rocha, A. 2015. *The present and future challenges of the Angolan economy*. Paper presented at the International Conference on the Emergence of Africa, 18–20 March 2015, Abidjan, Côte d'Ivoire.

Dionisio, T. 2014. Rebuilding Angola's infrastructure. *Infrastructure Journal* (London).

Golub, S. and Prasad, V. 2016. *Promoting economic diversification and international competitiveness in Angola.* Geneva, Switzerland: United Nations Conference on Trade and Development (UNCTAD).

Gomes, E. and Weimer, M. 2011. *Education in Angola: Partnership Opportunities for the UK.* London: Chatham House.

Habgood, L. 1998. *Health and livelihoods in rural Angola: A participatory research project*. Oxfam Working Paper Series. Oxford, UK.

Ministério da Indústria (MIND). 2014. *Indústria*: *Revista.* Luanda.

Ministério de Energia e Águas (MINEA). 2015. *Sustainable energy for all: Rapid assessment and gap analysis: Angola*. New York: United Nations Development Programme (UNDP).

Ministério do Ensino Superior. *Anuário Estatístico do Ensino Superior*. 2014, 2015 and 2016. Luanda.

Salgueiro, J.A. 2017. *Sub-sectores da Energia e Águas.* Luanda: Ministério de Energia e Águas.

BOTSWANA

BOTSWANA is a landlocked country bordered by South Africa to the south and south-east, Namibia to the west and north, Zimbabwe to the north-east and Zambia to the north.

It is the second driest country in southern Africa after Namibia, with up Botswana to 70% of its territory being in the Kalahari Desert. It is also one of the world's most sparsely populated countries, with a population density of just over four people per square kilometre in 2018, which ranked 221st in the world, out of 233 countries.

While Botswana was rated as having the highest Human Development Index among continental sub-Saharan African countries in 2015, some 20% of the people were unemployed and just over 18% lived below the international poverty line. Botswana has the second-highest HIV/AIDS prevalence rate in the world. In 2017 about 17% of the population was estimated to be infected, placing a substantial burden on the economy.

Gaborone is the largest city and the capital. More than 10% of the population lives in the capital and the majority of the population lives within 100 km of Gaborone. By 2017, some 68.7% of the population had urbanised, and the current urbanisation rate is 2.3% per year.

THE ECONOMY

Formerly one of the poorest countries in the world, Botswana has transformed itself into a strong economy based on mining, cattle farming and tourism.

The major change in fortune came with the development of diamond reserves, commencing in the 1970s. The development of six main diamond mines from 1971 to 2003 has made Botswana the world's leading diamond producer by value and the second-largest by volume.

The recession of 2008 saw diamond production drop and led the country to realise the need for diversification, to be less reliant on diamonds. To address this need and boost economic growth, an Economic Stimulus Programme (ESP) was put in place to develop all sectors of the economy.

The concept of 'Prosperity for All' was introduced in Vision 2016 and continues in Vision 2036. Vision 2016 articulated the national aspirations of the country 50 years after independence and illustrated the government's commitment to stimulating and supporting business and entrepreneurial activities by facilitating and fostering partnerships with the private sector. Growth should come from not only increasing the agricultural production or extraction of raw materials, but also manufacturing and services, among others.

PLANS AND STRATEGIES

To address diversification aspirations, several important plans and policies have been drawn up, including:

- **Vision 2036** whose goal is to see Botswana transformed into a high-income country, where continued growth would be underpinned by a more inclusive, diversified and export-led economy. The main pillars are sustainable

Table 1: Botswana metrics

Population	
Total	2 254 000
Urban	68.7%
Rural	31.3%
Poverty, HIV, Unemployment	
Below the international poverty line	18.2%
HIV-positive	16.9%
Unemployment	20.0%
Human Development Index	0.698
Electricity	
Production kWh	2.527bn
Consumption kWh	3.636bn
Airports and Ports	
Airports	74
- Paved	10
- Unpaved	64
Kilometres of Services	
Roads	28 152
- Paved	7 892
- Unpaved	20 260
Rail	888
Africa Infrastructure Development Index	36.79
Access to Services	
Access to safe drinking water	97%
- Urban	99%
- Rural	85%
Access to improved sanitation	74%
- Urban	93%
- Rural	46%
Access to electricity	66%
- Urban	75%
- Rural	54%
Telephones	142 122
Mobile phones	3 233 986
Internet users	63%

economic development; human and social development; environmental sustainability and good governance; peace and security.

- **Eleventh National Development Plan (2017–2023)**, known as NDP 11, which aims to develop a diversified economy, moving away from reliance on the mining sector, and ensuring that domestic expenditure and increased exports become the source of growth and employment creation.
- **Botswana Development Corporation Strategy (2014–2018)** aimed at *'doubling the business in 5 years'* by supporting emerging industries, sustaining critical industries and driving rural industries. The idea is to promote regional cooperation through strategic investment partnerships with regional peers.
- **Integrated Water Resources Management Plan (2005–2030)** which recognises the need to shift from meeting the water demand through the development of surface and groundwater resources, to adopting an integrated approach with an emphasis on demand management solutions and coordination across all sectors.
- **Energy Master Plan (2004–2019)** which aims to improve access to and the affordability of energy services, focusing mainly on renewable energy and, in particular, harnessing solar energy to grow a sustainable PV/SWH market through the creation of financing schemes and integrating grid and non-grid electrification.

If all of these plans and policies come to fruition, not only will engineering skills be required for development, but operations and maintenance teams will need to be significantly expanded to ensure that the new infrastructure is adequately maintained, and that the manufacturing sector is adequately resourced.

ENGINEERING ACTIVITIES

Figure 1 shows the contribution of engineering-related economic activities to the country's GDP. By far the largest sector is mining, followed by construction. Considering each in turn will give a picture of the activities, trends, challenges and opportunities for the engineering profession to contribute to Botswana's growth.

AGRICULTURE

As Botswana is such a dry country, with mostly sandy terrain, agriculture consists mainly of livestock, and the production of sorghum and maize. Raising cattle has long been the most profitable farming activity. The beef industry is well established, and over 95% of production is exported. Agriculture has been in decline since the 1960s. Its contribution of 42% to the GDP in 1996 reduced to just 2% in 2014.

In 2009, only 45% of farmers had access to roads, 17% to electricity, 43% to water for irrigation, 39% to grain storage and 52% to markets. This has resulted in slow agro-industrial and supply chain development, which is needed to drive the growth of subsectors such as food processing and manufacturing.

In terms of crops, only about 0.7% of the total land area is arable. Most of the land under cultivation is in the eastern region. The principal crops for domestic use are sorghum, corn and millet. The industry is dominated by small traditional farms with an average size of 5 ha. In 2012 there were about 63 000 arable farms falling into this category, while only 112 farms were larger than 150 ha.

Subsistence farming

There is very little commercial crop production, and most crops are produced for subsistence, or for sale locally. Traditional farming methods, recurrent drought, erosion and disease hamper crop production. To offer protection from drought, the

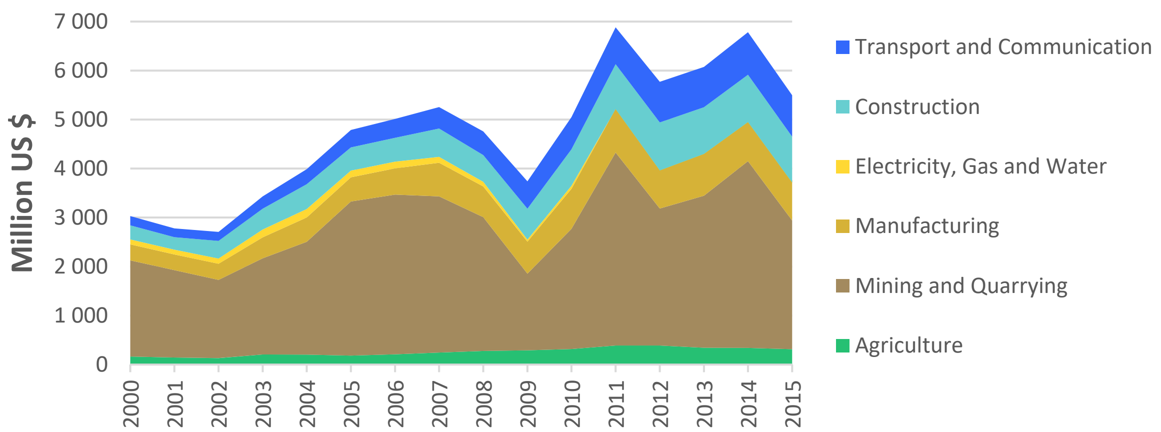


Figure 1: GPD per engineering-related economic activity (42% of the GDP)

construction of dams and the drilling of boreholes to tap underground water are continuing government programmes. Government schemes also aid with livestock purchase, breed improvement and subsidies for the purchase of seeds and ploughing and weeding equipment.

Due to the difficult farming conditions, the government changed its official agricultural policy to emphasise the production of only those foodstuffs that can be raised economically. The Arable Lands Development Programme (ALDEP) and the Tribal Grazing Land Policy are government programmes designed to help farmers in communal areas.

Commercial farming

The beef industry is the only agricultural subsector of that has constantly remained a significant contributor to the national GDP. Within the commercial sector, there are intensive livestock production systems. The constraint to crop farming is the supply of water. The country's current irrigated area could be increased substantially, with good economic returns. Simulations suggest that with a threshold internal rate of return (IRR) of 6%, it would be economically viable to develop a further 25 796 ha of land for irrigation, of which 98% would be large-scale projects.

Part of the ESP, discussed later, will focus on improved industrial production, with a long list of activities requiring engineering expertise, including:

- The facilitation of processing, packaging and marketing of agricultural produce
- Optimal use of grey and raw water
- Provision of infrastructure in production areas, more especially power, water and road infrastructure.

Forestry

The extent of forests is very limited, with six gazetted forest reserves covering only 1% of the total land area, whereas other wooded land covers 60% of the land area. Deforestation is a problem and commercial timber logging is negligible. Reforestation policies have been put in place to redevelop forests and promote trade in forest products to alleviate poverty and generate economic opportunities.

MINING AND QUARRYING

Botswana has abundant natural resources such as diamonds, silver, copper, nickel, coal, soda ash, potash and iron ore. In 2013, Botswana was the world's leading producer of diamonds by value, accounting for 26% of the value of global mined diamond production. Diamonds accounted for about 82%, copper and nickel for 7.1%, and soda ash for 1.1% of mining exports.

Diamonds are extracted using open-pit mining techniques. The two major diamond mines are Orapa and Jwaneng. Orapa's pit, shown in Figure 2, descends to a depth of 250 m and is expected to reach 450 m by 2026. A third mine, the Letlhakane Diamond Mine, is closed due viability challenges; however, a tailings mineral resource process was commissioned in January 2018. A fourth mine, Damtshaa Mine, produces just over 500 000 carats a year, which is small by comparison with the 12 to 15 million carats produced by Orapa and Jwaneng respectively. Debswana, which is a 50/50 partnership between the Botswana Government and the De Beers Group of Companies, is the second-largest employer after the government, with over 5 000 employees and 6 000 contractors. Some 97% of its employees are Batswana.

Figure 2: Orapa Diamond Mine, 2018

(Courtesy: Debswana)

Plans are in place to develop a copper and silver mine, to rework gold tailings, and the new Tau underground gold mine should be ready for production in 2018. Investigations are also underway to develop the large iron ore deposits in south-western Botswana, which are thought to be an extension of the Sishen deposit in South Africa.

The Botswana Investment and Trade Corporation suggests many activities for investment and development, including developing the coalfields, extracting coal bed methane, coal to liquids (CTL) and the extraction of soda ash. The latter will contribute to chromium production and to a range of manufacturing activities, including fertiliser and animal feed production, pulp and paper and detergents, among others.

Operating costs in Botswana are a challenge, especially where mines do not have access to the electricity grid. With the domestic demand for power increasing, the largely untapped and extensive coal reserves need to be explored with a view to developing coal-fuelled power stations. However, the setup costs of a mine are such that coal must also be exported to offset these costs, but as the current rail network is inadequate, this will also need to be developed, along with external markets.

MANUFACTURING

Manufacturing in Botswana contributed about 6% to the GDP in 2014. In 2016, the diamond industry, including processing and mining, employed some 12 700 people and manufacturing employed just over 37 500 workers. Botswana's manufacturing and processing concerns are predominately private sector enterprises, which include food and beverages; clothing and textiles; timber, pulp and paper; engineering and metal industries; and plastics and chemicals.

To reduce dependence on imports and increase exports, an Economic Diversification Drive (EDD) was launched. As a result, the government has invested significantly in the manufacturing sector in the form of subsidies and incentives to set up production plants and ensure that products are competitively priced, meet quality standards and can be reliably supplied. Unfortunately, this has not yielded the desired results due to, among others, energy challenges, a poor work ethic in the labour force, inefficient government bureaucracy and restrictive labour laws.

To overcome some of these difficulties, a policy was put in place in late 2010 to develop Special Economic Zones (SEZs), which would be geographically distinct

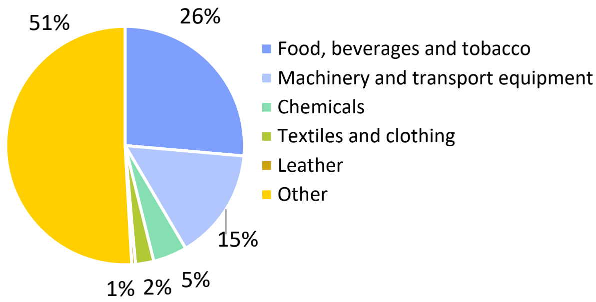


Figure 3: Manufacturing value add per subsector

economic areas, to provide investor-friendly business zones to attract both domestic and foreign investment. SEZs were planned to function with special administrative, regulatory and fiscal regimes different from those of the domestic economy. The identified areas for SEZs were:

- Gaborone (adjacent to the Sir Seretse Khama International Airport) – International diamond activities and specialised manufacturing
- Gaborone Fairgrounds – Financial services
- Lobatse – Beef, leather and biogas park
- Greater Palapye – Integrated coal value addition
- Selebi Phikwe – Mineral beneficiation
- Tuli Block – Horticulture and agro business
- Francistown – Mining supplies, services and logistics hub
- Pandamatenga – Integrated farming and agro business
- Business and food processing.

Sadly, by 2017, these had not materialised, but are considered essential by many to grow the manufacturing and services sectors. Botswana continues to import some 80% of its goods from South Africa.

Food, beverages and tobacco products

With Botswana being a major beef producer, many companies are involved in the production of a range of processed and canned meat products for local consumption and export. To beneficiate agricultural products, a horticultural process plant was commissioned in 2015. There are several food-processing factories producing precooked meals, oil, butter, margarine, peanut butter, sugar, biscuits and jam.

There are three main, and several smaller, milling companies. They mill sorghum, maize and wheat to produce a range of flours, maize meals, soya-sorghum weaning food, porridges, pasta and malts used for sorghum beer brewing. Botswana is a net importer of grain, and other products such as breakfast cereals are made in South Africa. UHT milk, maas and butter are produced locally, generally using imported milk. However, towards the end of 2015, milk production also commenced in Botswana. Fruit juices are also made locally and many animal feed manufacturers produce feed for cattle, pigs and poultry.

There are many breweries in Botswana, brewing a large range of beers, under international licences, and local opaque beer known as Chibuku from maize or sorghum. Bottled water and a range of internationally recognised carbonated soft drinks are bottled locally under licence.

Textiles, clothing and leather

In the early 2000s, 12 companies across the country took advantage of funding and support from the Textile and Clothing Industry Development Programme (TCIDP) to either develop or grow their businesses. Although some of these companies are now dormant, there are several companies, some employing as many as 500 people, involved in the industry. They manufacture, among other things, T-shirts, protective clothing, school uniforms, sports and denim wear, and blankets. The raw material and items required are mostly imported, but some are sourced locally. A spinning mill also produces yarn. Many of the larger companies export substantial portions of their production to South Africa, Zimbabwe and Namibia.

Botswana produces some 350 000 cattle hides per year that are used by furniture manufacturers locally, elsewhere in Africa and in Europe. Leather garments and footwear are also produced locally.

Timber, pulp, paper and packaging

With the limited supply of timber available in Botswana, most timber building supplies are imported. Several companies, however, produce cardboard cartons, toilet papers, serviettes and garage roller doors using imported raw material. Nampak, which opened its first plant in the country in 2011, plans to build two further facilities.

Plastics, chemicals and other non-metallic mineral products

Plastic products for industrial and domestic applications, including bottles, furniture, packaging film, refuse bags, PVC electrical conduits, HDPE pipes and fittings, PVC-U pipes for water, sewer and drainage networks and water tanks, are among the products manufactured, mainly for local consumption.

In terms of chemicals, 30 000 automotive batteries are produced per year and are sold throughout the region.

Paints, detergents, cosmetics, fertilisers and insecticides are some of the many products manufactured.

Cement has been produced in Botswana since 1996, along with allied products such as admixtures, cement bricks, cement blocks and precast products. Dense soda ash, light soda ash and salt are also produced.

Pharmaceuticals

The Botswana Vaccine Institute (BVI) produces local vaccines for foot and mouth disease in cattle and exports to the region. The Institute is the only drug-production facility that manufactures and exports medication from Botswana. Other than vaccines, only basic pharmaceutical products are produced locally. The balance of the country's pharmaceutical needs is imported.

Metal industries, machinery and equipment

To stimulate growth and support more local manufacturing, a steel manufacturing plant was commissioned in 2015. A foundry produces metal castings. Metal products that are produced include steel fencing and related items, steel and wire goods for the construction industry and steel pipes. Cans for food packaging are also manufactured.

Volvo, the Swedish Motor Company, assembles SCANIA trucks and Volvo buses and trucks in Botswana for export to neighbouring countries, and opportunities exist to produce components and supply this assembly plant.

ELECTRICITY, GAS AND WATER

Electricity

In 2013, 66% of the population had access to electricity, made up of 75% of the urban population and 54% of the rural population. The Botswana Power Corporation (BPC) is responsible for generating, transmitting and distributing electricity. As part of the ESP, Botswana aims to transition from an energy deficit to an energy surplus nation. This will allow for the accelerated electrification of additional villages, as well as an overall expansion of the number of households with access to electricity.

To generate sufficient capacity to address the targets, Botswana aims to grow the installed power capacity through the 300 MW expansion of the Morupule B Power Station and the development of the Sechaba coal and solar power plants. Botswana's total power generation is planned to grow from

0.42 TWh in 2016 to 3.2 TWh by 2025, with the country planning to become a net exporter of energy.

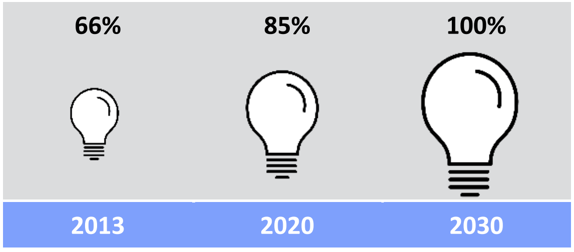


Figure 4: Target dates for access to electricity

Solar energy, harnessing Botswana's excellent sunshine of over 3 300 h per year with a quality of 22 MJ/h, is of paramount importance. Applications are already quite significant and are growing at a steady rate. They include solar water heating for domestic and commercial uses, solar desalination to provide potable water, passive solar buildings and photovoltaic devices for lighting, water pumping, refrigeration, communication and fence electrification. There are also plans to harness independent power producers (IPPs) to set up 20 mini hybrid power stations in isolated villages as part of plans to boost electricity access.

There are limited transmission lines in the north-west region and inadequate capacity to support new developments – particularly those of IPPs. Three developments, namely ZIZABONA to link Zimbabwe, Zambia, Botswana and Namibia, the North West Transmission Grid Connection (NWTGC) and a southern system to link the east and south-east to South Africa, are planned.

The NWTGC Phase I will see the construction of a 400 kV backbone transmission line from Morupule B to Maun via Orapa, two 400 kV substations and 220 kV/132 kV lines and substations connecting Toteng, Ghanzi, Shakawe and Gumare to the 400 kV line. Phase II will see the extension of the 400 kV grid from Phokoje (Selebi-Phikwe) to Pandamatenga via Dukwi and a 220 kV line to Kasane/Kazungula. This will reduce dependency on power imports from countries such as Namibia, Zimbabwe and Zambia.

Oil and gas

Botswana has no known oil reserves and its fuel and oil requirements are imported, mostly from or via South Africa. Multi-national oil companies distribute and sell fuels and lubricants.

To ensure security of supply, a study carried out for Botswana Oil has suggested the construction of an oil storage facility with a capacity of 150 million litres in Tshele Hills, expansion of the Francistown facility by 30 million litres and the construction of a Gantsi oil storage facility with 15 million litre capacity to augment the existing two government storage installations currently in use. Another option considered was to use coal to liquid (CTL) technologies, harnessing the vast coal reserves.

Botswana has independently certified gas reserves and it is expected that the first gas-to-power plant could be online by 2019, by tapping the country's coal bed methane (CBM) reserves.

Water and sanitation

Despite the arid conditions, 97% of the population had access to safe drinking water in 2015, made up of 99% of the urban population and 85% of the rural population. The same was not true of sanitation, as only 74% of the population had access to improved sanitation, made up of 93% of the urban population and 46% of the rural population. Due to the dry conditions, access to flush toilets is limited to 32.2% of the population, mainly in urban areas. Water and sanitation services are provided by the Water Utilities Corporation (WUC).

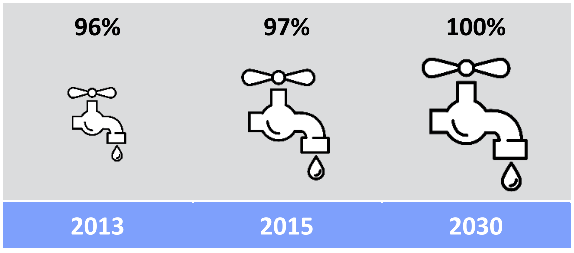


Figure 5: Target dates for access to safe drinking water

To expand water-borne solutions will be difficult and costly, given the sparsely settled rural areas. High evaporation rates and a deep watertable mean that most rural water supplies are from boreholes that are deep, making the exploration and operation of such wells difficult and expensive. Expanding access to flush toilets and improved latrines in the years to come is a major challenge, as is keeping pace with the urbanisation trend.

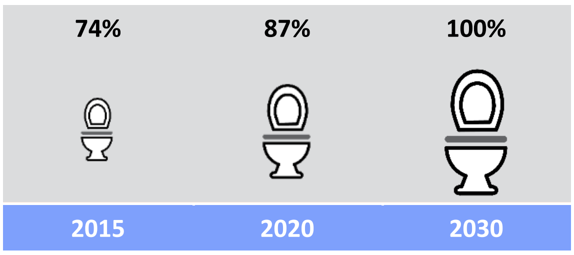


Figure 6: Target dates for access to improved sanitation

An Emergency Water Security and Efficiency Project for Botswana was launched in 2017, funded by the

World Bank, to improve the availability of water supply in areas vulnerable to drought, increase the efficiency of the WUC and strengthen wastewater management in selected systems.

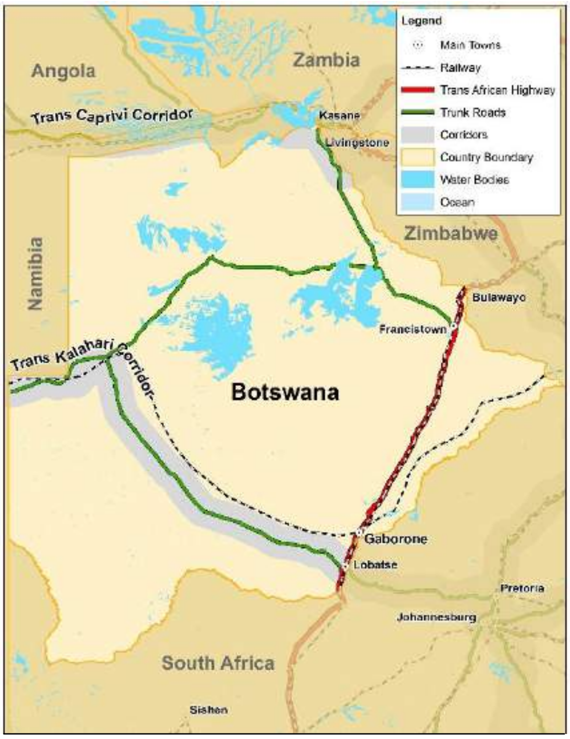
TRANSPORT AND COMMUNICATION

As the country is landlocked, good transport and communication networks are essential for trade. Botswana is connected to the ports of Walvis Bay, Maputo and the Gauteng industrial heartland through the Trans-Kalahari Corridor, which is composed of the Trans-Kalahari Highway and, in time, the 1 500 km Trans-Kalahari rail line.

All transport, communication and related services fall under the Ministry of Transport and Communications (MTC).

Roads

Botswana has made remarkable achievements in its road sector, expanding its total paved road coverage from just 12 km at independence in 1966 to about 7 892 km in 2008. Some 8 000 km are national roads, which are the responsibility of the Department of Roads in the MTC, and the balance fall under the jurisdiction of the district councils. The total network consists of 28 152 km. Many road developments and upgrades are planned, as outlined under *Construction*.



Disclaimer:
Aurecon gives no warranty of any kind, expressed or implied, with regard to the map or data whether for its reliability, accuracy or completeness and shall not be held liable in any event for any loss or damage in connection with or arising out of the use of this data or map. The Client accepts all inherent limitations of the maps and data, including the fact that the maps and data are dynamic and in a constant state of maintenance, correction and revision. The data and map remain the sole property of the CLIENT and may be used for purposes of this Project with the prior written approval from the CLIENT. aurecon

Figure 7: Transport corridors

Rail

Botswana's railway network consists of a main line of 640 km connecting Ramatlabama on the border with South Africa to Bakaranga in the north, and branch lines linking Francistown to the Sua Pan soda ash and salt mine (174.5 km), Palapye to the Morupule Colliery (16 km), Serule to Selibe Phikwe (60 km) which serves BCL mine and the Tshele line (14 km heavy haul).

The most significant development, which is in the planning stage, is the 1 500 km railway project to link South Africa and Botswana to the Namibian coast. Since this project is estimated to cost US$18 billion, the countries are looking to the private sector to fund it. Such a development will also increase the export potential for Botswana's considerable reserves of coal. In August 2010, Mozambique and Botswana signed a Memorandum Of Understanding (MOU) to develop a 1 700 km railway through Zimbabwe to carry coal from Serule in Botswana to a deep-water port at Techobanine Point in Mozambique.

Airports

A major upgrade to the Sir Seretse Khama International Airport in Gaborone was completed in 2017, more than doubling the airport's capacity. An upgrade to the Maun Airport Terminal to be completed in 2018 will allow the airport to accommodate large aircraft such as the Boeing 737, which, along with an upgrade to the Kasane Airport facilities, will accommodate more than double the number of tourists.

Communications

Botswana Fibre Networks (BoFiNet) has a very well-established fibre backbone, called the Trans-Kalahari fibre ring, focusing connectivity between Francistown and Gaborone, while also connecting all other major towns into the network and providing connections to all neighbouring countries. Each country is connected with a 48-core fibre cable, providing both redundancy and expandable bandwidth. International connections are accomplished mainly through South Africa where Liquid Telecom is a major role-player in connectivity with a variety of submarine cables. International connections are also provided through Namibia to the SAT-3 submarine cable, as well as radio and satellite links to neighbouring countries and international connections to the UK, US and Canada.

Although Botswana has a very well-established fibre backbone, internet penetration is still relatively low at 63%, with only 2.9% of the population making use of fixed-line broadband, 59% using mobile broadband and the remainder making use of other technologies.

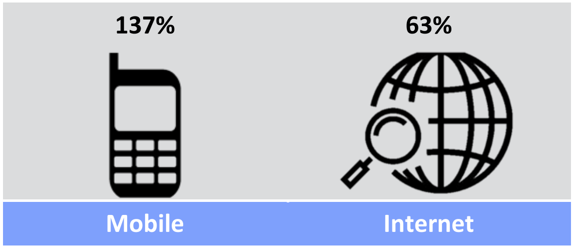


Figure 8: Percentage of population connected to services

The three major providers of mobile telephony services are Mascom, Orange and Botswana Telecommunication Corporation (BTC), the latter being the national government provider and the only provider of fixed-line telephone services. Fixed-line telephony connections have continued to drop, with only 6% having a landline subscription. On the other hand, 137% of the population had a mobile subscription in 2017, down from 150% in 2016 as more control is being implemented to reduce redundant connections on the network.

Botswana also plays host to the Square Kilometre Array (SKA) radio telescope system currently being developed. The SKA will consist of thousands of dishes and antennas spread over large distances, linked together to form a giant telescope. Taking part in the SKA project will enable the country to participate in and contribute to science research, as well as enhance its scientific capacity.

CONSTRUCTION

Construction is important in any country due to its ability to create jobs and develop skills. The construction industry employed some 23 000 people in 2016.

Currently several energy projects, roads, bridges and irrigation and drainage networks are under construction, and structural work includes the construction of schools, hospitals, hotels, high-rise commercial buildings and precincts. Major projects to be developed are listed in Table 2.

Much construction work is carried out by foreign companies, mainly from China, South Africa, Italy and, more recently, South Korea. Sadly, local companies have not been awarded major projects, as they are often eliminated in the early tender adjudication stages due to technical or qualification deficiencies. Furthermore, mega projects are seldom packaged to allow small local construction companies to participate or partner with foreign companies to ensure the growth and development of local capacity.

Many major projects have been developed by the Chinese in the past, but the quality of work has been such that the President announced in 2013 that Chinese contractors would be blacklisted for their track record of poor workmanship. Of concern is the fact that many routine projects such as schools and community centres, have also been awarded to foreign contractors, which could have been handled by local companies.

Table 2: Major projects identified, or being planned or under construction

PROJECT		VALUE US$	START YEAR	END YEAR
Energy	Morupule B Power Plant 300 MW upgrade	$790m	Under review	
	North West Transmission Grid Connection (NWTGC)	$480m	2018	
	Zimbabwe–Zambia–Botswana–Namibia Interconnector	$223m	2019	2021
	ZIZABONA Transmission Line	$200m	2017	2019
Water	Mahalapye wastewater reclamation plant	Tender	2019	
	Masama West well-field and 100 km pipeline to Gaborone	Tender	2019	
	North-South Carrier (NSC) Transfer Water Scheme Phase 3 – water from the Chobe and Zambezi	$2.8bn		
Roads	1.2 km-long, cable-stayed Mohembo Bridge	$100m	2017	2020
	Boatle–Game City dual carriageway	$170m	2017	2019
	Francistown–Nata Road	$350m	Pre-feasibility	
	Kazungula Bridge	$229m	2015	2019
	Metsimotlhabe–Molepolole dual carriageway		TBD	
	Palapye–Martins Drift Road		TBD	
	Pandamatenga–Nata Road		TBD	
Rail	Coal Rail Corridor – Botswana to Mozambique		Funds to be raised	
	Mosetse-Kazungula – to Zambia	$1.3bn	Funds to be raised	
	Trans-Kalahari Railway to Walvis Bay – funds to be raised	$18bn	Funds to be raised	
Other	Square Kilometre Array (SKA)	$450m		2023
	Jwaneng Cut 8	$24bn		2024

Quality concerns have not been limited to projects executed by Chinese contractors. A detailed study highlighted many weaknesses in the construction sector, including:

- Poor and incomplete designs by consultants
- Shoddy workmanship and incomplete projects by contractors
- Cost overruns due to the above-mentioned issues
- Rampant corruption
- Poor project implementation and management by the client
- Late and poor payments by the client to the contracting bodies.

The industry finds itself with no forum for discussing and tackling the issues it faces, such as sourcing information relating to cost/price indices, the weakness of clients, service providers such as consultants and suppliers, the increasing trend of corruption and Chinese dominance of the industry.

To address the skills-related challenges, registration of professionals (discussed later) has become compulsory in Botswana. It will also be important to revisit civil engineering and construction management qualifications to ensure that students understand their roles and responsibilities in the project cycle and that they are adequately trained in the workplace to manage construction projects and service providers.

Recognising the significant infrastructure development required for growth, a dedicated ministry, the Ministry of Infrastructure and Housing Development (MIHD) was set up in 2016. Part of their mandate is to develop 20-year rolling plans, and to develop a cadre of *'…technocrats with integrity who are properly selected and incentivised'* to lead mega projects and take the country to their goal of middle-class status.

The Public Procurement and Asset Disposal Board (PPADB) registers contractors wishing to bid for central government's procurement and asset disposal in respect of works, supplies and services.

Housing

Since gaining independence in 1966, Botswana has had a land allocation system that entitles every Motswana citizen to at least one plot of land. But cases of people applying to Land Boards and waiting decades before being allocated a plot are common. The situation has deteriorated in recent years as the demand for accommodation in Gaborone has driven the price of housing through the roof. A study carried out in 2009 revealed that 43% of households lived in inadequate accommodation – either in overcrowded formal dwellings or in informal dwellings. Sadly, the price of land and the building costs associated with even a basic house are way beyond the pocket of almost half the population.

The parastatal, Botswana Housing Corporation (BHC), was established to provide housing to Batswana of all income groups, but now produces houses that are out of the reach of most, much to the dismay of the general population. Another government initiative is the Self-Help Housing Agency (SHHA), which is specifically targeted at low-income groups. Those earning an annual income of between US$440 and US$3 640 are eligible to apply for low- to middle-income plots. Under further initiatives such as the Destitute Housing Programme, 771 houses were built between 2012 to 2016 in remote communities or settlements. The Presidential Housing Appeal went beyond remote areas, delivering a total of 2 550 houses country-wide between 2009 and 2016 as reported in the NDP 11.

The government also has plans to create an affordable housing scheme that can benefit citizens earning above the threshold for the SHHA but below the threshold to qualify for mortgages through financial institutions. For those who can afford housing, there is a thriving property development sector.

LOCAL GOVERNMENT

Botswana has 16 Councils made up of 10 District Councils and 6 Urban Councils. Their responsibilities include providing primary schools and other educational infrastructure, the management of sanitation, the removal and disposal of refuse, and the safeguarding and promoting of public health and safety. This includes waste management and the provision of public lavatories and emergency services. Additional engineering duties are the construction and maintenance of public roads and streets other than those constructed and maintained by central government. This includes the provision of street and traffic lights. They are also responsible for providing and managing municipal buildings and amenities such as markets, recreation grounds, public places and cemeteries. The development of schools has been taken over by the Boipelego Education Project Unit falling under the Department of Technical Services in the Ministry of Education and Skills. It has been found that having a dedicated unit is more efficient than relying on individual municipalities.

The Botswana Association of Local Authorities was set up to help build and strengthen local authorities when more duties were assigned to them.

EDUCATION, TRAINING AND PROFESSIONAL DEVELOPMENT

Education and training is a vital part of developing engineering capacity. All elements, from teaching appropriate subjects at schools to continuing professional development (CPD), need to be in place to educate and train engineering personnel and to ensure that they remain abreast of the latest technology, challenges and emerging solutions. According to the 2017/2018 Budget Strategy Paper, the education sector is faced with the challenge of a mismatch between graduates and job market requirements.

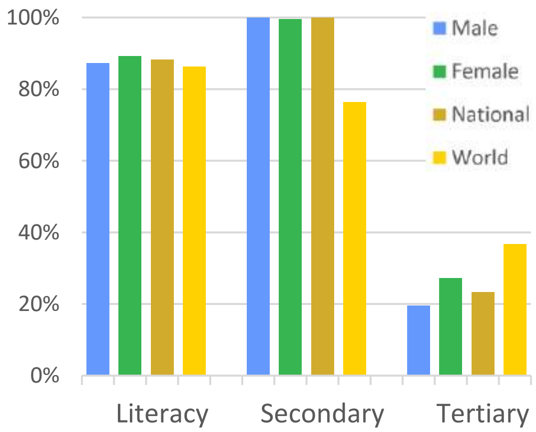


Figure 9: Literacy and enrolment statistics (only lower secondary is presented)
(UNESCO from 2014 to 2017)

PRIMARY AND SECONDARY EDUCATION

Primary and secondary education is composed of a seven-year primary phase, three years of junior secondary, followed by two years of senior secondary education, which is essential for acceptance into tertiary education. Education at secondary level is neither compulsory nor free.

Due to the critical shortage of well-trained workers to staff in the public service, education has been given the highest priority in the allocation of resources. Studies by the Southern and Eastern Africa Consortium for Monitoring Educational Quality (SACMEQ) over the years have shown improvement in the teaching of mathematics and literacy, and enrolment in lower secondary has topped 100%.

TERTIARY EDUCATION

By 2010, there were two public universities and seven private higher education institutions offering degrees and post-graduate qualifications, along with more than 50 colleges and providers registered with the Botswana Qualifications Authority (BQA) offering various diplomas and certificates. In Botswana there is overlap between the universities and colleges in terms of qualifications offered. Colleges offer foundation and trade certificates all the way up to advanced certificates for the training of technicians, and universities offer diploma courses for technicians all the way up to engineering degree and post-graduate studies.

The growth in private institutions has been encouraged to assist Botswana with reaching its target of 25% enrolled in higher education by 2026. There are, however, only ten institutions that offer engineering diplomas and degrees, as shown Table 3. Using the 10 level Botswana National Credit and Qualifications Framework (BNCQF), diplomas are set at level 6 and the four-year Bachelor Honours degree is at level 8. Just over 700 engineers, technicians and technologists graduated in Botswana in 2015.

The Botswana College of Engineering and Technology (BCET) has offered a range of engineering qualifications since 1990, including certificates, diplomas and higher diplomas. In early 1996, the Botswana University (BU) established the Faculty of Engineering and Technology, and many diploma and higher diploma qualifications were discontinued in favour of engineering degrees. With the advent of mining in Botswana, mining and mineral diplomas and degrees have been introduced. The BCET continues to offer a range of engineering diplomas.

The Botswana College of Agriculture (BCA), which was established in 1991, transitioned into a fully fledged university known as the Botswana University of Agriculture and Natural Resources (BUAN) in 2016 and now offers diplomas, higher diplomas and degrees in agricultural engineering, water conservation and soil engineering.

The Botswana International University of Science and Technology (BIUST) was founded in 2005 and started offering engineering qualifications in 2013. The first graduates were in mining and energy systems. Civil and computer engineering qualifications were first offered in 2015, hence NQ (for None qualified at the time of writing) is shown in Table 3. The Botswana Roads Training Centre was set up in 1962 to produce graduates for road development to support the construction industry. The Centre offers certificates and a three-year diploma in road construction.

Of concern has been the increase in the number of diplomas offered by private colleges using City and

Guilds (C&G) qualifications (not listed in Table 3). The C&G level 3 diplomas are rated at level 5 on the BNCQF and are not recognised by the Engineers Registration Board (ERB) as they do not offer the level of theory and problem-solving expected of a technician. Many students are graduating with these qualifications and are unable to secure work at technician level, as employers complain of their inability to apply basic engineering principles. The C&G level 5 advanced diploma is considered to be equivalent to a technician qualification, at level 6 on the BNCQF. The graduation statistics are shown by institution and category in Figure 10 and by discipline and category in Figure 11. Unfortunately, the split by gender was not available.

The attrition of academics is a growing problem. This is mainly due to increasingly attractive packages in the region and the demand for experienced professionals. To grow younger academics, Botswana University has accessed funds from the Newton Fund through the first phase of the Royal Academy's Higher Education Partnerships for sub-Saharan Africa (HEPSSA). The University is acting as the 'hub' university, working with 'spoke' higher education institutions in Eswatini, Namibia and locally. The objectives of the initiative include:

- Securing industry attachments for teaching staff to facilitate skills acquisition
- Establishing and strengthening departmental advisory boards to enhance the industry relevance of qualifications
- Engaging industry professionals to provide guest lecturers, seminars and professional development workshops, and inspiring students through practical exposure to the workplace.

Table 3: Engineering graduations in Botswana in 2015

*(*Eng = engineer, Tno = technologist, Tni = technician)*

INSTITUTION	QUALIFIC-ATION	*Recognised by ERB & category	Agriculture	Civil	Computer or Software Eng	Electrical & Electronics	Water & Environmental	Industrial	Mechanical	Mining & Metallurgy	Telecommuni-cations
Universities											
Botswana International University of Science and Technology (BIUST)	BEng	Y Eng		NQ	NQ	NQ				NQ	
Botswana University of Agriculture and Natural Resources (BUAN)	BSc(Eng)	Y Eng	42								
	Higher Diploma	Y Tno									
University of Botswana (UB)	BEng	Y Eng		28		15		9	12	11	
	Diploma	Y Tni								31	
Botho University	Advanced Diploma	N Tni			203						
Colleges											
Botswana College of Engineering and Technology (BCET)	Diploma	Y Tni		33		35	38		49		
Botswana Roads Training Centre	Diploma	Y Tni		25							
Limkokwing University College of Creative Technology	Assoc. Degree	N Tni			13 (2014)						
New Era College	Advanced Diploma	Y Tni				18					9
Botswana Accountancy College (BAC)	BSc (Hons)	Y Tno			90						
ABM University College	Advanced Diploma	Y Tni				13					
TOTAL											
Engineer (117)			42	28		15		9	12	11	
Technologist (90)					90						
Technician (471)				58	216	66	38		49	31	9

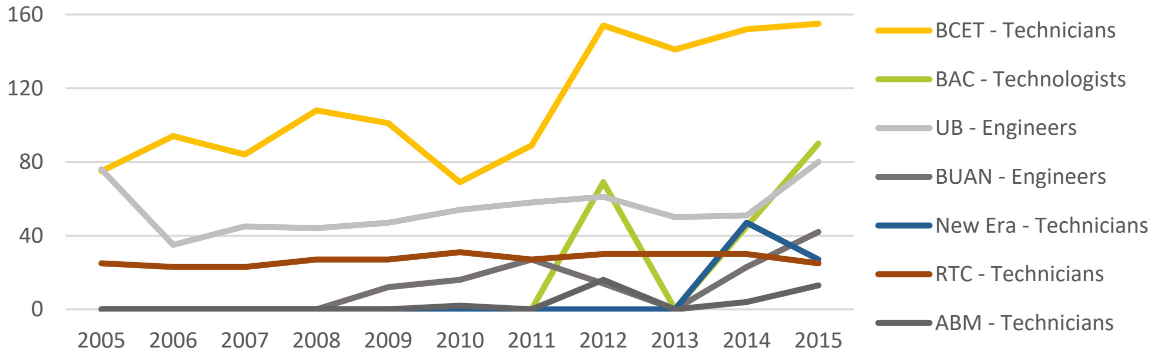


Figure 10: Graduates by institution and category

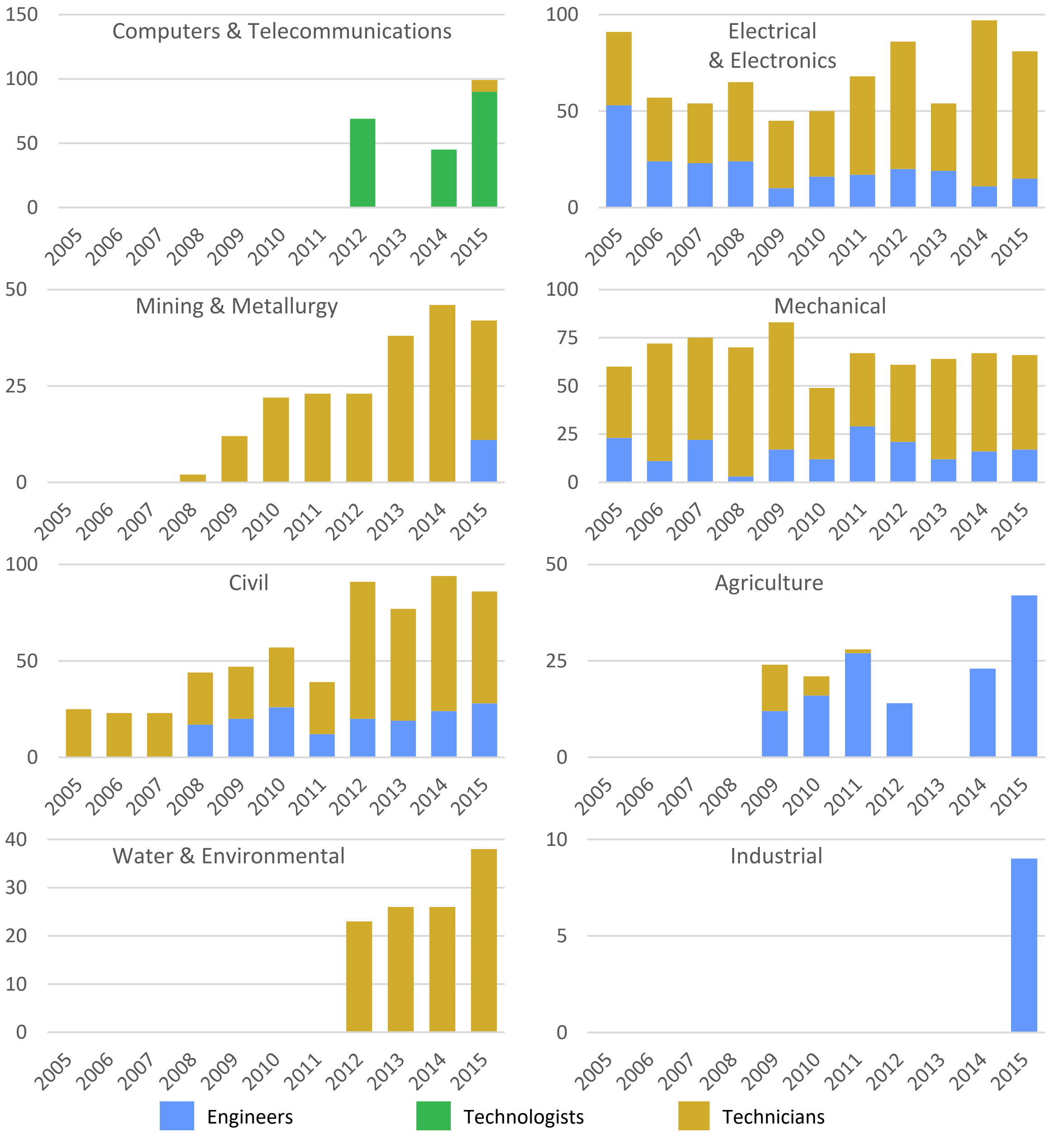


Figure 11: Graduates by discipline and category as recognised by the ERB

BOTSWANA

Accreditation

The ERB works with the BQA to review and accredit engineering qualifications. Of concern is the fact that there are several qualifications that are being offered as engineering qualifications, which are not recognised by the ERB, as shown in Table 3.As a result, graduates with these qualifications will not be in a position to register as professional engineers, engineering technologists or technicians.

The University of Botswana is working towards recognition under the Washington Accord with the help of the Engineering Council of South Africa (ECSA). As the university is relatively new, laboratories and equipment are largely up to date, but building an adequate team of academics in terms of numbers and qualifications requires attention. The development of the curricula to ensure that graduates are able to solve problems and have adequate skills to enter the workplace is also receiving attention.

Student mobility

In 2015, there was a total of 2 286 Batswana studying at South African universities, of whom 1 084 were studying by correspondence, through the University of South Africa. A total of 28 engineering students graduated – seven completing degrees, 11 BTechs and 10 national diplomas.

Over the years, more than 50% of all Batswana practising in the country in 2015 had studied abroad, with 21% having studied in the UK, 7% in South Africa, 4.4% in Canada, 2.7% in Zimbabwe, 2.6% in the USA, 1.8% in Australia and smaller numbers in countries such as India, Malaysia, China, Zambia, Malawi, Kenya and Russia, among others.

Despite having increased the number of higher education facilities that offer engineering training, the government continues to offer bursaries for students to study outside the country. The most popular destinations are the UK, the USA and China.

GRADUATE TRAINING

Once the tertiary education phase is complete, it is necessary for graduates to receive structured training in the workplace, under professional supervision and mentorship, to develop to the level of competence required for professional registration, and to be able to take on work independently.

The number graduating has increased substantially over recent years and many graduates struggle to find employment opportunities. This situation will be exacerbated once all new engineering qualifications come on stream at BIUST and more students graduate.

While the parastatals and Debswana have formal training programmes for graduates, which have been in place for many years, the same is not true of other departments and much of the private sector, and sadly, few if any graduates are offered training on projects awarded to international companies.

Industry complains about the quality of the graduates and the investment required to offer comprehensive coaching and mentorship. Industry needs to play a more significant role to ensure that their needs are considered when qualifications are being designed or updated. Industry also needs to accept that graduates do require comprehensive support to develop.

It is suggested that graduate training becomes part of the terms and conditions of all public sector projects, with adequate coaching, mentoring and support to ensure that graduates achieve the outcomes discussed in the next section.

PROFESSIONAL REGISTRATION

The enactment of the Engineers Registration Act CAP 61:06 in 1998, amended in 2009, signalled the government's commitment to the development, upgrading and promotion of professional engineering practice.

This move was considered necessary to protect clients and the public from unscrupulous persons or organisations whose principals did not have the requisite qualifications or experience to 'sign off' on designs, leading to unsafe engineering designs, systems and structures. In 2015, Prof. Oagile Kanyeto, then president of the Botswana Institution of Engineers (BIE) explained, *'We've had major problems with big projects not finishing on time or to the standard expected. There have been issues of people handling projects when they are not properly qualified and issues of bad conduct, overcharging and obtaining projects by unethical means'.*

The ERB was formed in 2010. It has taken time to set up the Board, administration, application and assessment system, etc., and registration was officially required as of 1 April 2014. A cut-off date of 31 March 2015 was set, beyond which those who were not registered with ERB would not be allowed to practise.

In May 2017, 3 019 were registered, but since then the ERB has stepped up efforts to get everyone to register. In August 2018, a total of 4 798 had registered, as shown in Table 4. The ERB's original goal was to ensure the registrations reached 90% by 2021. As it was estimated that there are some 5 500 to 6 000 engineering practitioners in the country, they have done well to achieve their goal ahead of time. It is conceivable that there are more engineering practitioners than initially envisaged – the number could be as high as 7 000. The ERB plan to carry out another census in 2019, now that they have developed such a good feel of the industry. There has, however, been unhappiness with their threats of legal action should practitioners not register. Expatriate engineers are also being targeted to register or leave the country. This is of concern, as there is a shortage of experienced engineers able to mentor recent graduates.

The Registered category is cause for concern. Applicants who are found to have inadequate experience for registration as professionals, but who have had three or more years of experience, are given interim registration. They are required to return for re-assessment once they have had sufficient experience to satisfy the outcomes prescribed for professional registration, but many simply use the ERB Registered certificate to show that they are registered, and clients without intimate knowledge of the ERB system would believe that this certification signifies a competent registered professional. The biggest percentage increase in registrations since 2017 has been in this category.

The ERB was set up to protect the industry from those not competent to take responsibility for complex engineering work. They need to exercise caution in driving registration for the sake of it, rather than to ensure competence. The Registered category needs to be withdrawn urgently. The degree of complexity of work and the outcomes achieved need to be assessed rigorously when registering professionals, as it has been found that engineers registered by the ERB are not always considered to be competent for registration by the Engineering Council of South Africa (ECSA).

Table 4: Registration with the ERB, August 2018

CATEGORY	TOTAL	%
Graduate Engineer	1 019	21.2
Graduate Engineering Technologist	184	3.8
Graduate Engineering Technician	887	18.5
Professional Certificated Engineer	6	0.1
Professional Engineer	1 270	26.5
Professional Engineer (Temp)	2	0.0
Professional Engineering Technologist	123	2.6
Professional Engineering Technician	357	7.4
Registered Engineer	523	10.9
Registered Engineering Technologist	113	2.4
Registered Engineering Technician	314	6.5
TOTAL	**4 798**	**100**

VOLUNTARY ASSOCIATIONS AND CONTINUING PROFESSIONAL DEVELOPMENT (CPD)

Once they have registered and are practising, it is important for professionals to continue with their development to keep pace with the latest technology, research, alternative solutions and current standards and legislation. CPD is the means by which professionals maintain and enhance their knowledge and skills and is a requirement of most registering bodies.

To support the registration process, and create CPD opportunities, the BIE has created a panel of training providers, calling on those interested to submit course proposals and their credentials for validation with the Institution. The aim is to offer a range of relevant courses each year.

The BIE represents the interests of all engineering practitioners in Botswana. Formed as the Botswana Society of Engineers in 1983, it was rebranded in 1995 to ensure high standards of qualifications, training, professional conduct and ethics among its members. It also promotes the general benefits and advancement of engineering to stakeholders and the country at large.

Member disciplines include agriculture, chemical, civil, construction, electrical, mechanical, mining and metallurgy. The BIE has some 1 800 members, which it estimates represent 25–30% of all engineering practitioners in Botswana.

WOMEN IN ENGINEERING

The Society of Women Engineers Botswana has been created to allow women to network and showcase their work, as encouragement for others. The Society sees mentorship as an important element of support and is in the process of setting up a directory of women available to offer mentorship to young female engineers.

THE WORKFORCE

According to research carried out by the ERB when formulating the need for, and role of, a registering body, there were about 5 500 to 6 000 engineering practitioners in Botswana. Using the model at the time, the age and gender distribution is shown in Figure 12.

Most organisations are small, with about 50% employing between one and three engineers and technicians. Less than 10% employ more than 15 individuals and these are generally government departments, parastatals and mining houses.

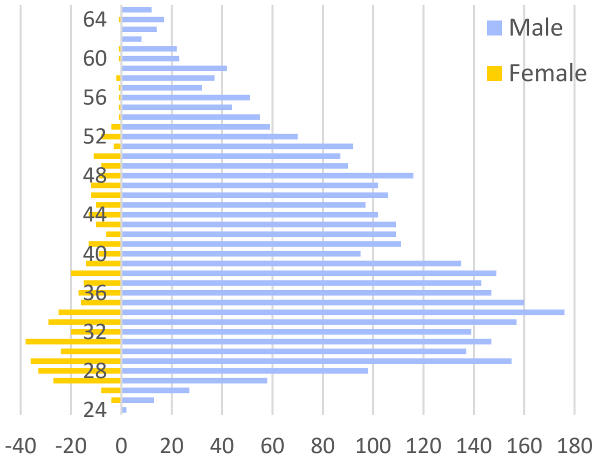


Figure 12: Engineering practitioners in the workforce by age and gender, based on the ERB survey

THE PRIVATE SECTOR

The main employers in the private sector are consulting, contracting, manufacturing, supplier and mining companies. Lower numbers are employed in small entrepreneurial companies, NGOs, training organisations and other companies where engineering input is required.

Consulting

The Association of Consulting Engineers Botswana (ACEB) represents the interests of some 45 consulting engineering firms in Botswana, although there appear to be some 80 consulting firms, including smaller firms and electrical, geotechnical and water resource consultants. It is estimated that they employ some 400 to 500 engineering practitioners. The consulting firms complain of a significant drop in local consulting opportunities as many major projects are let out on a turnkey basis, and are invariably won by international companies. This means that there is limited or no local input on final designs or local supervision.

Contracting

The contracting and construction supply companies in Botswana employed a total of 23 000 in 2016, of whom it is estimated that 500 to 600 are engineers, technologists and technicians. As outlined under *Construction*, the quality of work, lack of control and limited training taking place echo the challenges relating to professionals, as described earlier by Prof. Kanyeto.

The PPADB, which has been in place since 2011, registers contractors wishing to tender for public sector projects under three categories – works, services or supply. Under each category there are many subcategories, including building, civil, electrical, mechanical engineering works, and many smaller and specialist areas. Companies may be registered in all three categories and many subcategories. Contractors are graded from A to E or OC and may only tender for projects falling within their specified grade. Grading OC refers to Owner Companies – meaning small local companies with a single local owner. Grading A is the lowest, allowing contractors to tender only for projects below a modest value and makes few demands on companies in terms of equipment, property and skills. At the other end of the scale, Grading E allows contractors to tender for projects of any value, but they are required to own significant amounts of plant, equipment and property, and must employ a range of engineering and related skills. These requirements apply only to contractors based in Botswana. International companies are currently not required to register with PPADB.

The interests of local contracting companies are represented by the Association of Botswana Building and Civil Engineering Contractors (ABCON). They generally represent only the larger contracting companies and have not been as effective as they would have liked to be in providing direction on how best the sector should be controlled. A draft bill was prepared several years ago, calling for better regulation and coordination of the industry, but the bill has never been passed.

Joint venture and training requirements with foreign companies were also to be included. The involvement of foreign companies and the lack of suitable skills in the sector have been voiced as matters of concern for many years. Palalani's paper titled *Challenges facing the construction industry* published in 2000 captures challenges that are still experienced today.

To develop artisanal skills, the Construction Industry Trust Fund (CITF) was established in 1991 to offer competency based modular training (CBMT) for developing and upgrading the skills of artisans and craftsmen to meet the demands and challenges posed by the building and construction industry.

Manufacturing

There were just under 1 700 manufacturing establishments, who in total employed just over 37 500 workers in 2016. It is estimated that there are some 500 engineering practitioners in manufacturing, the largest numbers being employed in the food and beverage sector.

Business Botswana and the Botswana Exporters and Manufacturers Association (BEMA) represent the business and manufacturing sectors, seeking to grow these sectors and identify and overcome bottlenecks. About 60 companies are registered with the Botswana Investment and Trade Corporation (BITC) seeking investment and export opportunities.

Mining

There are around 50 mining, quarrying and prospecting companies in Botswana, employing some 12 500 workers in 2016. In total they employ around 750 engineering practitioners.

Most companies are members of the Botswana Chamber of Mines which was established to serve the interests of the mining and exploration companies, and associated industries.

THE PUBLIC SECTOR

Many engineering practitioners are employed in the public sector, particularly in the infrastructure ministries and associated utilities. Those likely to employ substantial numbers of engineers, technicians and technologists are shown in Table 5. It is estimated that some 2 500 engineering practitioners are employed in the public sector, including municipalities. Utilities complain of a shortage of staff, with one utility recording 40% vacancies in engineering posts. Low salaries are said to be a contributing factor.

Although many agricultural engineers and technicians are trained in Botswana, they were not evident in the private sector but only in the public sector in the ERB survey.

MIGRATION TRENDS

Analysis of the United Nations Population Division statistics for 2015 shows a small net gain of

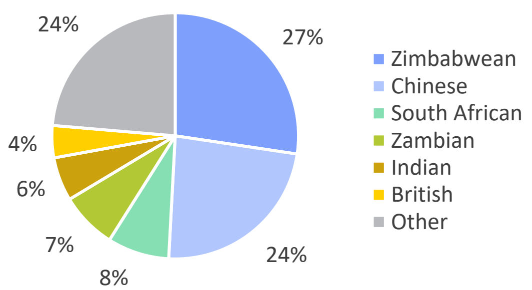


Figure 13: Nationalities of foreign engineering practitioners from the ERB survey

Table 5: Ministries employing engineering practitioners

MINISTRY/STRUCTURE
Ministry of Agriculture (MOA)
Ministry of Education and Skills • Department Technical Services (DTS) • Boipelego Education Project Unit
Ministry of Finance and Development Planning (MFDP)
Ministry of Health (MOH)
Ministry of Infrastructure and Housing Development (MIHD) • Botswana Housing Corporation (BHC) • Public Procurement and Asset Disposal Board (PPADB) • Engineers Registration Board (ERB) • Architects Registration Council • Quantity Surveyors Registration Council
Ministry of Lands and Housing
Ministry of Local Government (MLG) and all municipalities
Ministry of Minerals, Energy and Water Resources (MMEWR) • The permanent Okavango River Water Commission • Orange–Senqu River Commission • African Diamonds • African Copper • CIC Energy Corp • Debswana Diamond Company (Pty) Ltd • Morupule Colliery Ltd • Water Utilities Corporation (WUC) • Botswana Power Corporation (BPC) • Botswana Energy Regulatory Authority • Botswana Geosciences Institute
Ministry of Investment, Trade and Industry • Botswana Development Corporation • Botswana Investment and Trade Centre • Botswana Bureau of Standards
Ministry of Tertiary Education, Research, Science and Technology • Botswana Institute for Technology, Research and Innovation • Botswana Qualifications Authority • Human Resources Development Council
Ministry of Transport and Communications (MTC) • Air Botswana • Botswana Railways (BR) • Department of Central Transport • Department of Roads • Botswana Telecommunications Corporation (BTC) • Department of Broadcasting Services

professionals into Botswana. Of those entering the country, 35% were from South Africa, 30% from Zimbabwe and 12% from Zambia.

Almost 30% of BIE members are foreign, although in total 15% of engineering practitioners are foreign, with the distribution of nationalities shown in Figure 13. Chinese engineering staff tend to come and go according to construction sector activities, as construction is the second-largest employer of foreign personnel by percentage in the country (after manufacturing, which employs just over 20% of foreign personnel). The most popular destination for emigrants was South Africa, representing almost 20% of emigrations. In 2015, there were 340 foreign civil engineers, holding a work permit, working in Botswana.

ENGINEERING NUMBERS AND NEEDS

From the foregoing discussions it can be seen that engineering practitioners play a significant role in Botswana's economy. It is essential that the number grows to support diversification and economic growth and that a pool of high-calibre graduates is educated and receives comprehensive workplace training to augment the supply.

For the purpose of skills projections, a workforce of 6 000 is assumed in 2017. A 2015 scarcity survey reported that 56% of respondents had some difficulty in employing degreed engineers. Input received in the current survey indicates that there is a shortage of mining engineers and technicians, with the estimated shortage being between 20 and 50%.

Considering these views, which have been prevalent for some time, many newer institutions have started to offer engineering qualifications in recent years. In 2015, 120 engineers, 90 technologists and 470 technicians graduated in Botswana, as shown in Table 6. Adding the number returning after studying out of the country suggests that a total of 750 to 800 graduates would have been seeking employment at the time, i.e. 12.5% of the workforce. Once graduations from BIUST and other new universities commence, this is likely to increase to 900 or more.

However, considering the disciplines, it can be seen that some 300 have studied computer or software engineering. Clearly, the number is too high for the engineering sector and few will be able to find work in their chosen field. It could also be that many of these qualifications are not necessarily engineering but rather computer science. For this reason, the overall number of engineering graduates has been

Table 6: Numbers graduating in 2015 and in employment in Botswana

CATEGORY	GRADU-ATING	IN INDUSTRY	%
Engineers	117	3 319	3.6%
Technologists	90	417	18.1%
Technicians	471	2 264	20.8%

reduced by 45 technologists and 175 technicians for future projections, i.e. 120 engineers, 45 technologists and 295 technicians. An allowance of 8% for returning graduates and a further 80 graduates who will start entering the industry from new qualifications has also been included.

Figure 14 shows the current workforce, the losses that will occur over the 18-year period to 2035 due to retirement, mobility and mortality, and the growth in engineering capacity if local engineering graduations (including projected graduates from BIUST and Limkokwing) increase at 2% per year.

The blue dotted line shows the growth in skills that would be required at the 2017 GDP growth rate of 2.4% and the green dotted line shows the growth based on the 2018–2023 GDP projection of 4.3%. A 70% employment elasticity factor has been used to extrapolate the employment demand.*[1] Based on the projected growth and current workforce, graduations exceed demand. The graduations will only meet the demand should the Agenda 2063 targets be realised.

Major graduate training programmes will need to be put in place to offer graduates two or three years of experience so that they can take their place in local industry, become entrepreneurs able to develop new products, services and businesses, or be able to seek employment outside the country.

Rationalisation of enrolments in higher education training is required. Attention to the mix of qualifications needs to be given as follows:

- **Agricultural engineering:** There are very few agricultural engineers in practice in Botswana. Given the need to expand irrigation systems and post-harvest processes and management, it is essential that a flow of graduates is maintained from BUAN. Comprehensive graduate training needs to be put in place to ensure that graduates grow into problem-solvers and decision-makers, but the government and companies need to be made aware of the value and use of agricultural engineering practitioners.
- **Chemical engineering:** Some 80 to 100 degreed chemical engineers were employed in 2018. Although the numbers required are not high, these engineers are essential in food and

*[1] Employment elasticity is a measure of the percentage change in employment associated with a 1% change in economic growth. If the growth is likely to be in agriculture, the percentage could be lower, as growth in that sector generally has to do with productivity gains and not employment, while if the growth is likely to be in high-tech manufacturing, the elasticity factor maybe more than 100%.

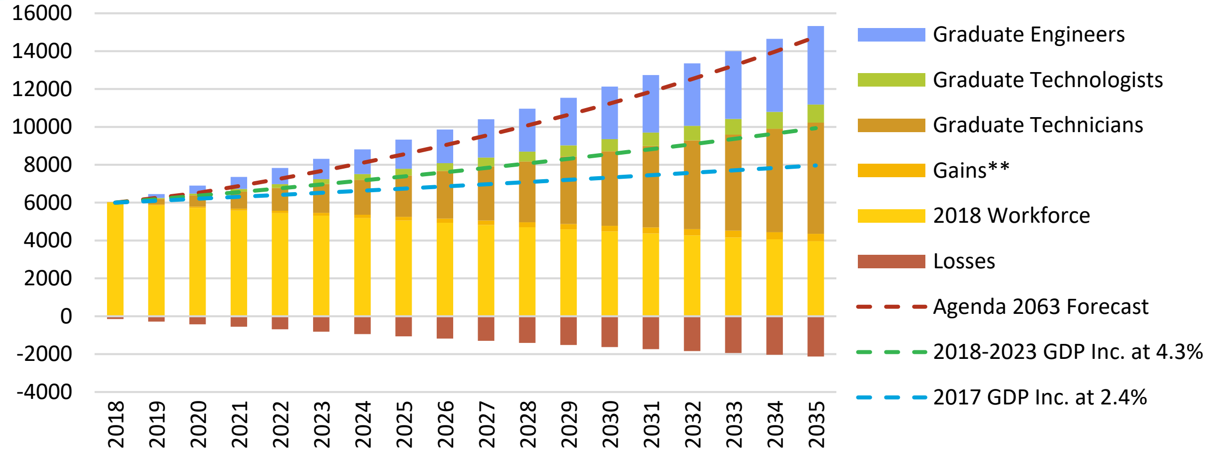


Figure 14: Flow of engineering skills based on a 2% increase in graduation rate per year

***Excludes international engineering practitioners in the country on short-term contracts and not registered with the ERB. Those registered with the ERB are included in the workforce.*

beverage processing, the petro-chemical industry and mining. A couple of bursaries for study outside the country should be offered each year until such time that it becomes viable to train chemical engineers locally.

- **Civil and environmental engineering:** Civil engineering practitioners represent the largest group of engineering practitioners – approximately 1 400 in total, 750 of whom are engineers. About 50 graduates are required each year. It is hoped that the numbers to graduate from BIUST from 2018 onwards will make up the shortfall. However, coordination between UB and BIUST will be essential to ensure that they do not compete with each other to supply graduates, rather than consider demand.
- **Electrical, electronic and software engineering:** The number of electrical engineers and technicians currently being trained appears to match the demand. However, the number being trained in computer and software engineering appear to be excessive.
- **Industrial engineering:** There are only a handful of industrial engineering practitioners and indications are that they are difficult to source. They could, however, play a significant role in terms of streamlining agricultural and manufacturing production processes and the efficiency of government structures. The first industrial engineering graduates emerged from UB in 2009 and a small number has graduated each year since then. A concerted effort should be made to link them with experienced industrial engineers for the first few years after graduation to gain appropriate experience.
- **Mechanical engineering:** There are major roles for mechanical engineering practitioners to play in manufacturing, mining and power generation, to name a few. There are some 400 to 500 degreed mechanical engineers in Botswana. The average rate of 16 mechanical engineers graduating from UB each year is too low to address the demand. More students should be encouraged to study mechanical engineering.
- **Mining engineering and metallurgy:** With the growth of the mining industry, mining engineers and metallurgists are key to productivity and quality output. Figure 11 shows the growth in the number of graduations since 2009. The challenge is to pair all recent graduates with experienced, mostly expatriate, mining engineers and metallurgists in the sector to grow a new, local cadre of mining professionals.

KEY RECOMMENDATIONS

To develop a sound pool of engineering professionals, able to contribute to the well-being of Botswana, the following should be considered:

Schooling

- **Career guidance:** Expand career guidance to attract high-calibre entrants into the engineering profession, incorporating programmes to reach female learners, and rural and low-income areas.
- **Bursaries:** Provide bursaries to attract those who excel in mathematics and science to study engineering.

Tertiary education

- **Accreditation:** Develop a rigorous accreditation programme in collaboration with the ERB to ensure the quality of engineering education using the guidelines of the Washington, Sydney and Dublin Accords.
  - Encourage institutions to develop adequate complex engineering problem-solving content and

graduate attributes to satisfy the requirements of the Accords.
  - Create awareness of accredited qualifications and warn learners of those that will not lead to registration as engineering professionals.
  - Withdraw qualifications which do not meet accreditation requirements.
- **Industry liaison:** Liaise with industry on a regular basis to ensure that curricula, methods, software and equipment are relevant and up to date.
- **Curricula:** Provide funding to research, modernise or develop curricula and material where required.
- **Attract and retain academics:** Improve conditions of service, support and packages to attract, retain and appoint additional academics.
- **Academic development:** Provide funding for lecturer post-graduate development and facilitate opportunities for academics to gain experience in industry.
- **Mechanical engineering:** Ensure that sufficient mechanical engineering students are enrolled each year.

Graduate training

- **Develop programmes:** Develop national graduate training programmes to ensure graduates achieve the level of competence required by industry and for professional registration.
- **Private sector incentives:** Offer incentives for private sector companies to develop graduates.
- **Public sector support:** Ensure that public sector structures take on and train graduates and that they are absorbed and developed through the ranks.
- **Institutional support:** Institutionalise graduate training in all organisations by setting KPIs for experienced staff to act as supervisors and mentors.
- **Project support:** Make graduate training a requirement of all public sector projects and ensure that the progress of graduates is monitored, and penalties are imposed for non-compliance.

Registration of engineering professionals

- **ERB development**: Support the ERB in its endeavours to build a robust registration body.
- **Registration categories:** Withdraw the category of registration known as Registered.
- **VAs:** Recognise and support the development of voluntary associations in the engineering sector.
- **Engineering census:** Repeat the census carried out to determine the size and shape of the engineering sector to gain a better understanding of the discipline, qualification level and sector requirements.

Continuing development

- **CPD:** Support the development of a robust CPD system, monitored by the ERB but rolled out by the VAs and tertiary education institutions, to include courses, workshops, conferences, online learning etc.
- **Validation:** Validate short courses and skills programmes for a specified period only to ensure that training remains up to date and relevant.
- **Post-graduate studies:** Provide post-graduate bursaries to develop specialists.
- **Develop managers and leaders:** Encourage industry to continue investing in graduates after professional registration to grow management and leadership capabilities.

Registration of service providers

- **Construction Bill:** Develop and adopt a National Construction Bill to:
  - Cover the increasing the use of local consultants, contractors, labour, plant and materials.
  - Ensure that foreign consultants and contractors partner with local companies.
  - Ensure that there are requirements for consultants and contractors to train graduates, artisans and other construction-related skills.
  - Ensure that international consultants provide all calculations, drawings, operating manuals and other reference material in English.
  - Ensure that local consultants, along with the client, check that design proposals address local needs and customs and that design calculations comply with national codes and standards.
  - Limit companies to a certain size or category of work based on their technical skills, past experience and the availability of plant and capital.
- **Quality:** Implement quality assurance on all projects and impose penalties for poor performance.
- **Turnkey projects:** Review the turnkey contract conditions to ensure the involvement of local professionals and provide adequate supervision to ensure quality of work and value for money.

The public sector

- **Maintenance:** Invest in maintenance to preserve new infrastructure and prevent further deterioration of existing infrastructure.
- **Technical capacity:** Reprioritise budgets to fill vacant posts and build technical capacity, ensure that salaries are competitive and develop succession plans to make the public sector an employer of choice.
- **Technical decision-makers:** Ensure that engineering professionals are employed in senior decision-making posts.

Industry-wide collaboration

- **Advisory team:** Set up an engineering advisory team, recognised by government, to advise on and endorse infrastructure development proposals, tertiary curricula and graduate training programmes.
- **Collaboration:** Encourage all professional bodies to work together to share knowledge, exchange best practice and ensure coordinated planning of industry support initiatives.

ACKNOWLEDGEMENTS

The detailed picture presented would not have been possible without the support of many associations, government departments and local professionals. Thank you to Prof. Oagile Kanyeto, President of the BIE and professor at UB, who assisted with graduate and BIE data and many views, Mercy Kgosidialwa from the ERB who assisted with ERB and research data, Cassius Mmopelwa from City and Guilds, Botswana and the team from the BQA who made national higher education information available. Thank you too to many government departments and companies who made information available and for ideas provided by passionate engineers in various consulting firms.

SOURCES OF INFORMATION

Data and information were gathered during meetings, interviews and telephone conversations, and via email. SADC reports, master plans and strategies as listed under *Plans and Strategies,* and many standard international sets of data as listed in Chapter 5, *Research Approach,* were also consulted. Further information was gathered from newspapers and from Statistics Botswana. Also very useful were the Botswana Investment and Trade Centre publications, which include the *Investor Handbook, Botswana's Competitive Business Advantage* and fact sheets covering the various subsectors. Comprehensive documents focusing on specific issues in Botswana as listed below were additional sources of information.

BEDIA Botswana (Botswana Export Development and Investment Authority) & IntoSA. 2013. *Botswana Investment Guide*. Pretoria: IntoSA.

Foster, J.D.G and Uziak, J. 2002. Engineering Education in Botswana. *International Journal of Engineering Education*, 18(6): 627–632.

Moletsane, K. 2009. *Local government system in Botswana*. Paper presented at the 55th Association for Local Authorities in Namibia (ALAN) Congress 25–27 March, Windhoek, Namibia.

Motlhanka, K. and Mapfaira, H. 2014. Growing manufacturing: Assessing Botswana's diversification efforts through manufacturing sector growth. Gaborone: University of Botswana.

Nthoiwa, G.P., Gombalume, T. and Mokwena Nthoiwa, K.K. 2013. Processing and utilization of sorghum and maize in Botswana: Current status and opportunities. *Asian Journal of Agriculture and Rural Development*, 3(11): 788-800.

Palalani, K. 2000. *Challenges facing the construction industry: A Botswana perspective*. Gaborone: Third Dimension Consulting.

Ssegawa-Kaggwa, J., Ngowi, A.B. and Ntshwene, K. 2013. Using a situation analysis to identify the construction industry deficiencies in Botswana. *Journal of Construction in Developing Countries*, 18(1): 1–18.

Statistics Botswana. 2017. *Census of Enterprises and Establishments 2016.* Report: Phase 1. Gaborone.

Tsa Badiri Consultancy. 2015. *Botswana Labour Market Scarcity Survey*. Gaborone.

University of Botswana Engineers Society. 2015. *The Engineers Registration Board (ERB) 2015 Survey of Engineers and Engineering Technicians.* Gaborone: ERB.

The DRC

THE DEMOCRATIC REPUBLIC OF THE CONGO (DRC) is the second-largest country in Africa and the largest in the SADC region. It is situated along the Equator and is bordered by Angola and Zambia in the south, by Uganda, Rwanda, Burundi and Tanzania in the east, by the Central African Republic and South Sudan in the north and by the Republic of the Congo in the west. A 45 km-wide strip of coastline in the west provides the country's access to the Atlantic Ocean. Five of the famous African Great Lakes form part of the eastern border.

The DRC has an extensive hydrographical network dominated by the Congo River, which spans 4 320 km across the country. It receives the highest rainfall in the SADC region, up to 2 400 mm per year in some places, and boasts the second-largest tropical forest in the world after the Amazon.

The country holds the world's largest deposits of cobalt and tantalum and significant reserves of copper, gold, diamonds and other minerals.

Despite its abundance of natural resources, it is one of the poorest countries in the world. More than 77% of the population live below the international poverty line and formal employment opportunities are limited. It has a young population. In 2017 the median age was 18.8 years according to the CIA.

Kinshasa, the capital city, is the most populous and important city, as it is a major industrial and urban centre. It is the third-largest urban area in Africa after Cairo and Lagos, and the world's largest French-speaking city, even surpassing Paris. More than five million people live in the fast-urbanising eastern part of the city, in largely slum conditions, with limited or no access to services or jobs.

Lubumbashi, which is the centre of the largest mining ventures in the country, is the second-largest city by population and is also home to many slum dwellers, while Mbuji-Mayi, the diamond capital, is described as being *'...one big slum'*.

THE ECONOMY

Before independence the DRC had the second-strongest economy in Africa, after South Africa. During the ensuing years of civil war, infrastructure was destroyed, and no maintenance or development took place, resulting in the DRC today having a GDP per capita of just US$887 in 2017.

The economy is largely reliant on the engineering sectors, with retail, wholesale and services in general having contributed only some 25–30% to the GDP for many years.

Economic and structural reforms have resulted in the gradual consolidation of the country's economic framework, but with developments being limited to sectors not conducive to major job creation, the prospects of an overall recovery are slim. Constraints to be overcome include lack of infrastructure, weak governance and institutional capacity, and an unconducive business environment.

Anti-government demonstrations escalated after President Joseph Kabila refused to step down in December 2016 on the expiry of his second and final term in office. As a result, the economy declined showing a drop of 6.7% in GDP from 2016 to 2017. It is hoped that the outcome of the elections, that were

Table 1: DRC metrics

Population	
Total	88 806 000
Urban	42.5%
Rural	57.5%
Poverty, HIV, Unemployment	
Below the international poverty line	77.1%
HIV-positive	0.4%
Unemployment	7.2%
Human Development Index	0.433
Electricity	
Production kWh	9.05bn
Consumption kWh	7.43bn
Airports and Ports	
Airports	172
- Paved	26
- Unpaved	146
Kilometres of Services	
Roads	153 497
- Paved	2 794
- Unpaved	150 703
Rail	4 007
Pipelines	895
- Gas	62
- Oil	77
- Refined products	756
Waterways	15 000
Africa Infrastructure Development Index	8.15
Access to Services	
Access to safe drinking water	46%
- Urban	79%
- Rural	29%
Access to improved sanitation	31%
- Urban	29%
- Rural	33%
Access to electricity	9%
- Urban	19%
- Rural	2%
Telephones	59 534
Mobile phones	28 889 317
Internet users	6%

held on the 30 December 2018, will be acceptable, and that the country will be able to chart a course to regain its former economic strength.

PLANS AND STRATEGIES

To achieve the turnaround required, several plans and strategies have been developed, including the following:

- **Vision 2050,** which aims to ensure that the DRC is a high-income country by 2050.
- **National Strategic Development Plan (PNSD) 2017–2021** aimed at achieving a middle-income status by 2021, focusing on transformation of the agricultural sector.
- **Growth and Poverty Reduction Strategy Paper (GPRSP) 2011–2015** aimed at improving living conditions by diversifying the economy, improving the infrastructure, governance and institutional capacity, and harnessing the private sector.
- **National Agricultural Investment Plan (PNIA) 2013–2020** aimed at promoting investment in agriculture, predominantly by the private sector.
- **Energy and Water Action Plan (2018–2035)** aimed at delivering medium-scale hydropower plants to electrify industrial zones, urban and smaller centres, using renewable energies to generate and distribute to provinces, and to increase the number of people with access to safe drinking water.
- **Rural Electrification Strategy** aimed at attracting private investment and operators, establishing schemes that are affordable, developing sustainable financial models and technical support structures, and promoting Renewable Energy Technologies (RET).
- **Sector Strategy for Education and Training (SSEF) (2016–2025)** aimed at reforming the sector at all levels, including increasing the capacity to deliver and attracting students into technical fields in higher education.

ENGINEERING ACTIVITIES

Figure 1 shows the contribution of engineering-related economic activities to the country's GDP. The largest sector is agriculture, followed by mining and manufacturing. Considering each in turn will give a picture of the activities, trends, challenges and opportunities for the engineering profession to contribute to the DRC's growth.

AGRICULTURE

The agricultural sector supports two-thirds of the population. Agricultural production has stagnated since independence. The principal crops are cassava, yams, plantains, rice and maize. The country is not drought-prone but is handicapped by a poor internal transportation system, which impedes the development of an effective food-supply system. To improve food production the PNIA targets support to smallholders, while also promoting industrial and cash crop production and the establishment of Centres of Agricultural Enterprises or Agri-Business Parks.

Subsistence farming

Despite favourable natural conditions, the agricultural sector has for many years been reduced to subsistence farming, which involves some 4 million families on plots averaging 1.6 ha (4 acres).

Small-scale farmers use rudimentary equipment, often only a simple hoe and watering cans. Although this sector generates low yields, it contributes about 80% to the country's food production. Traditional agriculture is rainfed with little or no use of irrigation.

As levels of conflict have escalated, conflict coupled with armyworm infestations have destroyed crops in over a quarter of the country, and are devastating for

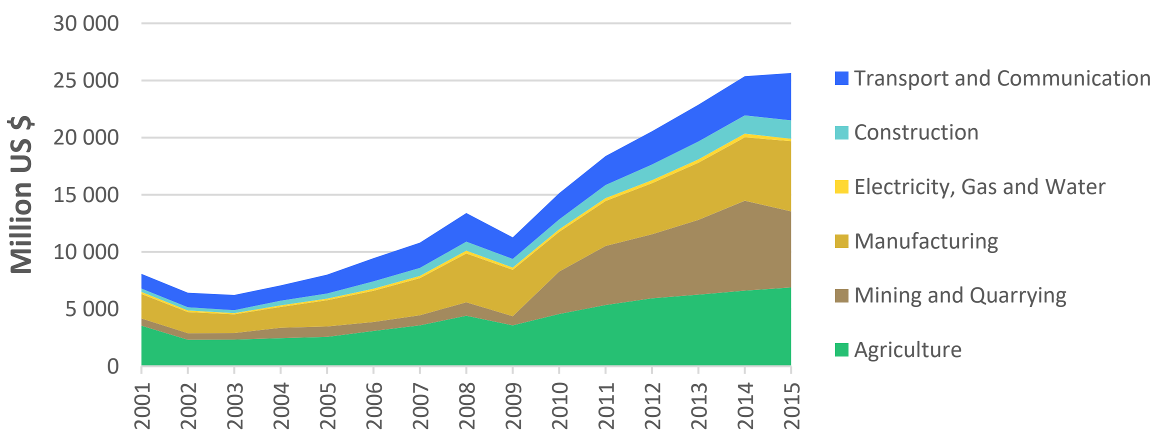


Figure 1: GPD per engineering-related economic activity (74% of the GDP)

rural communities, resulting in 7.7 million people facing acute hunger in 2017 – a 30% increase over 2016.

As part of the PNIA, the Small-Scale Farmers Initiative has been conceptualised to provide seeds, agricultural tools, mechanisation and fertilisers, and to rehabilitate or develop feeder roads to improve access to markets. The development of boreholes for improved drinking water is also a priority.

Commercial farming

The commercial agriculture sector consists of a few large agricultural businesses, which use modern production methods. Production of sugar cane, coffee, cocoa, palm oil, cinchona bark and rubber is mainly for export.

Irrigation is almost non-existent. Currently, the DRC irrigates only 0.1% of cultivated land, well below the African average of 5%. The country's water withdrawals are negligible relative to the total amount of renewable water available.

The need to grow commercial farming capacity and reduce food imports has led to the concept of Agri-business Parks. There are plans, using Public-Private Partnerships (PPPs), to develop 16 parks which will include greenhouses, storage and processing facilities, and the logistics for receiving and dispatching goods. The government has committed to invest in bulk infrastructure such as roads and electricity, to facilitate land tenure and to provide incentives in exchange for private sector farming expertise and business nous to develop export markets. They have also recognised the need to strengthen the technical and organisational capacities of public and private sector organisations to increase production.

Forestry

The DRC has the largest forests in Africa, and millions of people depend on the forests for survival, selling the wood and relying on the forest's biodiversity for food, housing and wood-based energy (80% of all the energy consumed in the country). Deforestation is of concern as land is cleared for farming.

Fisheries

There are vast freshwater fishery resources in the country, contained primarily within the major Rift Valley lakes. According to 1995 Frame Survey results, there were 417 landing sites along the DRC coastline and 10 650 fishing craft (most of which are dilapidated), hosting a total of some 26 300 fishers. Catches are well below the full potential and it is said that fish die of old age in the lakes! In 2016 it was reported that the annual fish catch was of the order of 120 000 tons. Given the considerable potential in this sector, many initiatives are underway to develop production, including the modernisation of fishery equipment and materials. The introduction of fish processing and conservation techniques is also important to reduce losses sustained in periods of overproduction or during transport.

MINING AND QUARRYING

The DRC holds extensive mineral wealth, with over 1 100 substances having been identified, 22 of which are at present economically viable. The major reserves are listed in Table 2.

The country is estimated to hold almost half of the world's cobalt reserves and significant reserves of tantalum, tin, gold and diamonds. The DRC will be a beneficiary of the booming cobalt industry. Since cobalt is used in rechargeable batteries (49% of the demand for cobalt is used for this purpose, including use in the electric vehicle market), future growth in global battery demand will support cobalt consumption and prices for decades to come. In

Figure 2: Kamoto Oliveira Virgula open pit copper mine in Kolwezi

(Courtesy: Kamoto Copper Company)

recent years there have been significant foreign private investments in large-scale industrial mining, which have contributed to macro-economic growth.

Table 2: Main deposits
(Investing DR Congo 2013, Africa Report)

ORE	RESERVES (TONS)
Copper	75m
Lithium	31m
Niobium	30m
Manganese	7m
Zinc	7m
Cobalt	6.7m
Iron (over 60%)	1m
Cassiterite	450 000
Gold	1 500
Diamonds (carats)	206m

Capitalising on low labour costs, high ore grades and untapped resources, many acquisitions, expansions and developments are planned, mainly by foreign investors, with particular interest from China, and substantial exploration is taking place. The main concern facing investors is the introduction of a new mining code, which will call for increased royalties and require mining companies to support localisation and the use of local subcontractors.

With copper prices having recovered since 2014, there has been renewed interest in copper, particularly as high grades (above 3% versus the global average of 0.6–0.8%) in some areas make investments attractive. To address the erratic power problem, mining companies have installed diesel generators to top up power supply for copper production, and others are building their own power plants. They will sell excess back to the grid.

The expansion and development of diamond and gold mines continues as the country possesses 30% of the world's diamond and 25% of its gold reserves.

Concern has been expressed that the capacity to grow is hindered by the shortage of mid-level skills and calls have been made for the private sector and government to collaborate on the training of artisans and technicians in the mining sector.

MANUFACTURING

The DRC exports most of its raw material, thus losing value and jobs to foreign countries. Manufacturing and processing companies are predominately private sector enterprises and include: food and beverages; clothing and textiles; timber, pulp and paper; engineering and metal industries; plastics; and chemicals. In 2013 the main manufacturing activities were distributed as shown in Figure 3.

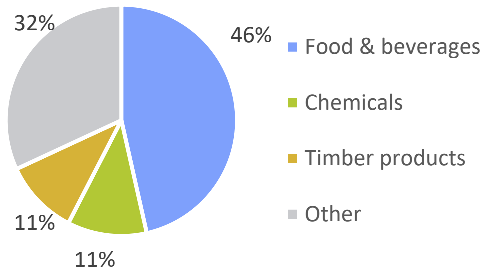


Figure 3: Distribution of manufacturing activities per subsector in 2013

The performance of the manufacturing sector does not reflect its production potential for several reasons, including lack of transport and energy infrastructure, obsolescence of production equipment, administrative and technical constraints, limited use of new technology and the limited size of the financial sector. In 2013 it was estimated that there were 647 formal manufacturing companies, more than a third of which are based in Kinshasa. Large manufacturing firms are generally foreign-owned, while small and medium enterprises (SMEs) are largely indigenous-owned.

The DRC is embarking on the establishment of special economic zones (SEZ) to encourage development. The first SEZ was planned to come into being in 2016 in Maluku in the eastern part of Kinshasa and will focus on agro-industries. Further zones are planned as shown in Table 3.

Food, beverages and tobacco products

A wide range of food products are manufactured, including grain products, biscuits, cereals, snacks, cured meat, peanut butter, oils, margarine, sugar, tea, coffee, dairy products, confectionary and condiments such as vinegar, mayonnaise and tomato sauce. There are several flourmills and oil factories

Table 3: Planned Special Economic Zones

ZONE	ACTIVITIES
1. West – Kinshasa–Inga–Matadi–Banana	Manufacturing around the seaports of Matadi, Boma and Banana, hydropower, production of oil and bauxite
2. Centre – Ilebo–Tshikapa–Kananga–Mbuji-Mayi	Transport logistics and food industries
3. South – Kolwezi–Likasi–Lubumbashi–Sakania	Heavy and manufacturing industries focused on copper, cobalt and others
4. East – Uvira–Bukavu–Goma–Beni–Bunia	Food and manufacturing industries
5. North-West – Kisangani–Bumba–Mbandaka	Wood industries and agri-business

but, sadly, a mill with a capacity of 300 tons per day recently built in Lubumbashi to process the region's corn into flour and semolina has yet to be connected to the grid, despite receiving political backing at the outset.

Many companies are involved in beverage production, with bottled water and a wide variety of beers, spirits, wines, juices, carbonated soft drinks and other beverages being produced. These include local brands and many international brands produced under licence, including Heineken, Guinness and the range of Coca-Cola drinks.

Agro-processing is considered so important that one of the PNSD's main objectives is the creation of 2 000 agri-businesses, by young graduates, in promising agro-pastoral areas which can generate 10 000 jobs. About 100 000 people representing producer organisations and other suppliers of input and materials for young people will benefit indirectly from the project. The cost of developing these parks is presenting a problem: the first four are estimated to cost a total of US$1.34 billion, and funding has not yet been secured.

Of concern is the fact that Nestlé announced that were to close their local plant in January 2018, citing the poverty and political climate as reasons for not making the operation viable. Bralima, the major brewery, is also restructuring its local operations and initiating several retrenchments as increasing taxes, the economic slump and the social situation continue to deteriorate.

Tobacco production has also reduced over the years and in 2014 British American Tobacco (BAT), the major producer in the DRC, closed its local operation and is now importing cigarettes from South Africa.

Textiles, clothing and leather

The once-booming cotton industry ceased exporting as far back as 1975, and the textile industry, known for its brightly coloured intricately patterned fabrics, has declined dramatically over the past ten years due to infrastructural challenges and lack of competitiveness. Cotton mills are no longer operational and only one textile factory, La Société Textile de Kisangani (SOTEXKI) has managed to survive. The other challenges are second-hand products, institutional instability and illegal imports from the East Asian countries.

Timber, pulp, paper and packaging

Given the extent of the forests, sawn wood production, or primary processing continues to be an important value-add. Logs, sawnwood, veneers, construction materials and matches are produced from a wide range of African species. In 2013, the DRC exported an estimated 144 801 tons of roundwood (logs), and 32 343 tons of sawn wood and timber exports were the sixth out of the top 10 exports reported in 2016. A range of papers, including toilet paper, paper towels and tissues, kitchen paper, serviettes and fine papers are manufactured locally, plus corrugated cartons and other packaging material.

Plastics, chemicals and other non-metallic mineral products

The full range of plastic pipes, fittings and manholes is manufactured for civil engineering, agricultural, mining and domestic applications, as are bins, water tanks, huts and other hardware items. In addition, plastic chairs, tables, a range of household items, polystyrene and PET bottles are produced by several manufacturers.

Rubber has slowly been re-establishing itself as a cash crop and a plant in Equator Province now produces 2 tons per hour of granulated rubber.

Batteries are produced using local resources such as manganese and zinc, and are in demand in the rural areas. Candles, wax, paints, perfumes, cosmetic and personal care products, and cleaning products such as soaps, detergents, washing and scouring powders, are also produced locally.

Substantial suppliers with an understanding of the range of chemicals required by the mines source products worldwide, but nonetheless require engineering expertise to ensure that specifications are met and to advise on preparation and usage.

The cement sector is growing, fuelled by infrastructure development and reconstruction. The production of cement locally has been increased by some 6 000 tons per day with the construction of two new plants in 2015/2016. Kerbs, pavers, breeze blocks and other cement and concrete products for the construction sector are also manufactured locally.

Pharmaceuticals

Although the country relies heavily on the importation of pharmaceutical products, local pharmaceutical laboratories manufacture a range of antibiotics, anti-malarial, anti-retrovirals, anti-pyretics, analgesics, anti-amoebics, anti-diarrheal and anti-tussive medication. Of interest is that fact that a local producer, PHARMAKINA SA, is the world's leading quinine producer.

Metal industries, machinery and equipment

Several companies are involved in the production of metal packaging for the food and beverage markets, while many construction products, including galvanised pipes, gutters, metal nozzles, nails, sheeting, reinforcing bars, aluminium and galvanised products, barbed wire, mesh, door- and window-frames are manufactured locally. The country also produces cables and meters.

As most machinery, equipment, private, commercial and heavy-duty vehicles are imported, engineers are employed in supply and distribution, rather than the manufacturing space, to assist clients with selecting and specifying the products required, and with installation and ongoing maintenance.

ELECTRICITY, GAS AND WATER

Electricity

Although the DRC has huge energy potential, only 9% of the population had access to electricity, made up of 19% of the urban population, and a low 2% of the rural population, in 2013. An aggressive target to provide 60% of the population with access to electricity by 2025 has been set, but few plans are in place to meet this target.

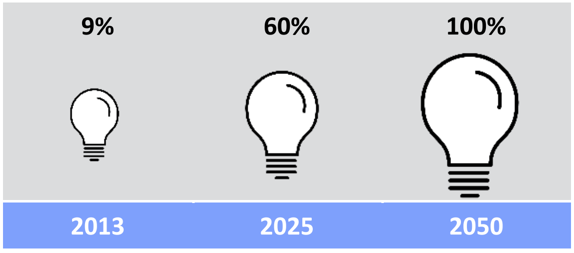


Figure 4: Target dates for access to electricity

Even in the urban areas, power outages are common, with businesses and households relying on generators for backup supplies. Damaged power plants and transmission lines, a shortage of spares, illegal connections and lack of skills contribute to this situation.

Société Nationale d'Electricté (SNEL) is the state-owned organisation responsible for the generation and supply of electricity. Only 2 540 MW, a fraction of the hydropower potential of the Congo River's hydraulic potential of 100 000 MW, has been developed, and only 1 100 MW of this capacity is in functioning order. There are two interconnected power systems – the first connects the Inga site in Bas Congo to Kinshasa and Brazzaville, as well as to Katanga and on to Zambia, and the second interconnects the two Kivu Provinces with Rwanda and Burundi. Both systems are dilapidated and need extensive rehabilitation.

The largest hydropower station is on the Inga Dam. However, the technology is out of date and only five out of 14 turbines are currently functioning. Due to these deficiencies, mining companies have developed their own local hydroelectric schemes at a cost of around 10 cents per kWh, compared with an estimated long-term national grid cost of less than 4 cents per kWh. The mines have also elected to purchase mobile substations to interface with the SNEL network during the construction phase for mining projects, as this is more cost-effective than using diesel generators.

Zambia's ZESCO Limited and SNEL are constructing a new 1 000 MW plant on the Luapula River on the border of the two countries (a project which has been on the drawing board since 1929!). To meet demands, refurbishments and an additional 35% of expansion capacity are required. To develop the export potential, a further 7 600 MW would be required, costing US$750 million per year over the next decade. Plans are underway to develop Inga III which will generate 4 500 MW.

The DRC has only 4 600 km of high-voltage transmission lines (above 110 kV) of which 1 725 km were developed to deliver power to the copper mines in Katanga. However, due to poor maintenance and theft, less than half the design power is being delivered.

SNEL complain of several challenges which hamper their ability to maintain, upgrade or extend the network, including the lack of funding or support from the government, low tariffs, poor recovery on invoices (receiving about 40% of the total billed) and a high level of technical and non-technical losses, chiefly in distribution.

In the absence of an independent regulator that can promote competition, set tariffs and ensure grid access for third parties, the electricity sector has failed to attract significant private investment, which would alleviate the situation to some extent.

The very high levels of sunshine make the installation of photovoltaic systems and the use of thermal solar systems viable throughout the country, with an estimated capacity of 85 MW. Some 836 solar power systems had been installed by 2013 and installations continue.

Oil and gas

Oil and gas discoveries in the east of the country give the DRC the second-largest crude oil reserves in Central and Southern Africa after Angola. The DRC has proven reserves of 180 million barrels, although estimates of total petroleum reserves exceed 5 billion barrels. Proven natural gas recoverable reserves at the end 2011 were 100 million cubic metres. The only oil refinery was closed in 1999 and all refined petroleum products must be imported.

Water and sanitation

The DRC has many major dams, but several in remote areas were developed for hydroelectric schemes.

Régie de Distribution d'Eau (REGIDESO) is the water utility responsible for producing and distributing water to residential, commercial and industrial customers. It is an autonomous utility which was founded in 1933.

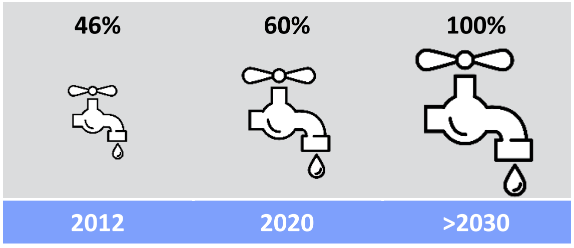


Figure 5: Target dates for access to safe drinking water

According to REGIDSO, only 46% of the population had access to safe drinking water, made up of 79% of the urban population and 29% of the rural population, in 2012. Only 31% of the population had access to improved sanitation facilities, made up of 29% of the urban population and 33% of the rural population.

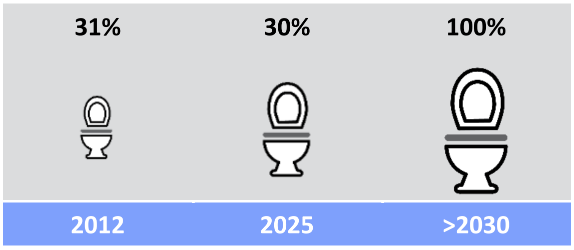


Figure 6: Target dates for access to improved sanitation

The government committed to providing safe drinking water to all districts, setting an ambitious target to provide 75% of the country by 2015. This target was not met, and with high losses, low tariffs and poor collections, the likelihood of reaching the target in the next few years is slim. Rural communities increasingly rely on the use of surface water.

The World Bank has committed to fund Projet d'Alimentation e Eau potable en Milieu Urbain (PEMU) which will focus on the modernisation and expansion of networks in Kinshasa, Lubumbshi and Matadi by 2020. Revised targets are shown in Figures 4 and 5. Dates for universal access to tap water and improved sanitation have not been set.

TRANSPORT AND COMMUNICATION

The transport network is multi-modal, made up of 16 238 km of navigable waterways, 4 007 km of railways built during the colonial era, 153 497 km of roads and urban thorofughfares, and 270 airports, including six international airports.

Movement using the various modes of transport is limited. The main domestic corridors are:

- Matadi–Kinshasa-Lubumbashi (road and rail)
- Bunia–Kisangani-Kinshasa (road and river)
- Lubumbashi–Goma (road).

Other capitals are connected only by air and there is an absence of transport links between provincial capitals and their rural areas. As the country is criss-crossed with rivers and waterways, the development of the network is expensive, due to the need for bridges and tunnels to traverse these barriers.

There are several international corridors that are important for trade and imports:

- The **Northern Corridor** links the DRC, Uganda, Rwanda and Burundi, Southern Sudan and Northern Tanzania to Kenya and is a multi-modal corridor, encompassing road, rail, pipeline and inland waterways; the road extends 7 000 km, of which only 60% is paved
- The **Central Corridor** links the DRC, Rwanda, Tanzania and Uganda and includes road, rail and various ports
- The **Southern Borders** link to Walvis Bay, Luanda, Dar es Salaam, Beira and Durban through a combination of road and rail
- The **Western Borders** link to ports in the Cameroon, Gabon, Angola and the Congo Republic.

Being a mostly landlocked country, the need for good road, rail and waterway services within the country and in neighbouring countries is evident as the country relies on external ports for trade. The responsibility for developing, operating and maintaining this network rests with National Transport and Ports Company (SCTP), previously the Office National des Transports (ONATRA) (National Transport Agency). The airports are operated by Régie de Voies Aériennes (RVA), the Congolese Airport Authority.

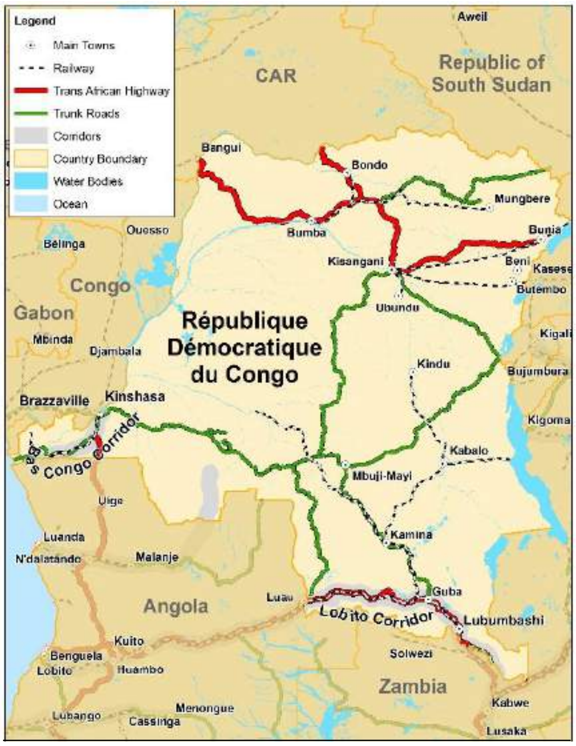
Roads

The country's road network is in an extremely bad state of repair following years of armed conflicts. In theory, the road network comprises 58 358 km of national roads. According to estimates, only 5% of the national roads are sealed. These sections are located mainly between Matadi and Kinshasa, Lubumbashi and the Zambian border, and some sections in the eastern part of the country.

National roads, including priority and secondary roads, are managed by the Office des Routes (OdR). The Office des Voiries et Drainage (OVD) is in charge of all urban roads comprised of sealed and paved roads, both of which fall under the Ministry of Infrastructure, Public Works and Reconstruction. Local or rural roads are managed by the Direction des Voiries de Desserte Agricole (DVDA) which falls under the Ministry of Rural Development.

Rail

The DRC has two separate rail systems – Chemin de Fer Matadi-Kinshasa (CFMK), a 366 km rail link from Kinshasa to the port of Matadi, and the Société Nationale des Chemins de Fer du Congo (SNCC), which operates an extensive network of 3 641 km centred in the south-east. The most important branch connects Kolwezi to Sakania on the Zambian border, and westward to Ilebo.



Disclaimer:
Aurecon gives no warranty of any kind, expressed or implied, with regard to the map or data whether for its reliability, accuracy or completeness and shall not be held liable in any event for any loss or damage in connection with or arising out of the use of this data or map. The Client accepts all inherent limitations of the maps and data, including the fact that the maps and data are dynamic and in a constant state of maintenance, correction and revision. The data and map remain the sole property of the CLIENT and may be used for purposes of this Project with the prior written approval from the CLIENT. aurecon

Figure 7: Transport corridors

The CFMK rail link is the natural transport mode for timber exports and other bulk traffic that is not time-sensitive, including imports to the city of Kinshasa. The current track is 30 years old and is in reasonable condition. The SNCC network is the natural transport mode for copper exports leaving the DRC for the port of Durban, or through Lobito in Angola via the reconstructed Benguela Railway, which was reopened in 2015. The CFMK and SNCC networks are not interconnected, so through-transport from Kinshasa to Lubumbashi has is achieved using the river link from Kinshasa to Ilebo, where the SNCC network begins.

Although the CFMK's track is in relatively good condition, its rolling stock has deteriorated, and its quality of service has declined. The SNCC network is in poor condition, causing many former clients to swap to road transport. The World Bank is overseeing and financing the rehabilitation and upgrading of large sections of the main line between Lubumbashi and the Zambian border crossing at Sakania, and mining companies have committed to finance upgrading various spur lines to access the newly upgraded line. The funding also covers new trains and boats and in 2015 the first new locomotives (from China) were delivered to Lubumbashi.

Waterways

The DRC has more navigable rivers and moves more passengers and goods by boat and ferry than any other country in Africa. Waterways provide the dominant mode of transport. Kinshasa, with 7 km of river frontage occupied by wharfs and jetties, is the largest inland waterways port on the continent. However, much of the infrastructure, vessels and port handling facilities, have, like the railways, suffered from poor maintenance. Where ONATRA once had 1 000 vessels, the current SCTP has only 20 ships and needs to rebuild the fleet to dramatically increase the volume of goods that can be transported. To support this growth, it will be necessary to rehabilitate and equip shipyards.

Ports

The Port of Matadi plays a critical role in the national economy. Matadi is a feeder port servicing Kinshasa and the south-west area of the country. It has a capacity of 2.5 million tons per year, but operates at only 2 million tons per year as it is physically constrained by its cargo-handling capacity and by the depth of the river, which has a draft of only 6.5 m. Matadi therefore cannot take direct calls from major international shipping lines, but relies on transhipments from Pointe Noire, in the Republic of the Congo, using smaller vessels. River sedimentation is further reducing the draft of the port, so routine dredging is needed to maintain navigability. Container dwell times average 25 days and crane productivity is a fraction of that found elsewhere, making it a very inefficient port. Other ports on the estuary of the Congo River are Boma (further inland) and Banana (closer to the mouth of the river).

Airports

Air transport has not been able to fulfil its role because of the dilapidated airport infrastructure and navigation equipment, and the extremely weak technical and safety regulations in the country. The DRC has 60 airports, including six classified as international airports, with N'djili Airport in Kinshasa being the major international airport. The majority are poorly maintained. As a result, large areas of the country remain unserved by air transport, the DRC's airspace poses high air navigation risks, and serious accidents and incidents have occurred in the past. This outcome is reflected in the DRC's failure to meet international air transport safety and security standards.

From an understanding of the transport network challenges, it is evident that a large team of engineering practitioners would be required to rehabilitate, expand, operate and maintain the infrastructure if funding should become available.

Communications

Mobile network operators are the principal providers of basic telecom services. In 2013 the country was connected to low-cost, high-quality international bandwidth through the WACS submarine fibre optic cable linking countries on the west coast of Africa to the United Kingdom. In 2015 the ACE, a fibre optic submarine cable linking west coast countries to France, was connected.

An international connection running from neighbouring borders to multiple submarine cables in Kenya and Tanzania will provide redundancy in the event that local submarine connections go down. Société Congolaises des Postes et Télécommunications (SCPT) is rolling out a fibre optic national backbone network with support from China, to connect the country to the fibre landing station in Muanda.

As of 2016, there were 28.89 million mobile device subscriptions, representing a 44% penetration rate while internet penetration was approximately 6.21% of the population. Hampered by poor physical infrastructure, mobile telephony has grown to fill the role traditionally filled by land-based telecommunications. With more people connected to mobile telephony than electricity, an entire market for charging of mobile phones has developed, with many small entrepreneurs offering charging services from generator-powered shops or small solar panels set up wherever there is a demand.

There are only 1 000 reported fixed broadband subscriptions, making the country's mobile telephone operators de facto internet service providers for private and commercial users.

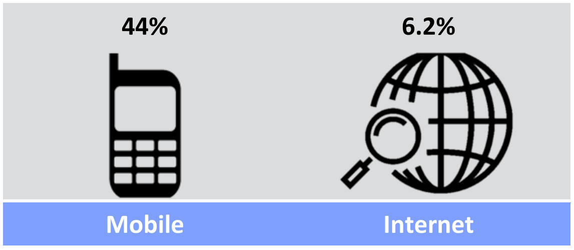


Figure 8: Percentage of population connected to services

CONSTRUCTION

Since the end of the 1990s there have been numerous infrastructure projects, largely financed by the World Bank and the European Union. The construction industry's annual growth rate between 2003 and 2008 was 7%. Infrastructure development also constitutes an essential component of the country's agreements with China. The construction industry has suffered a decline in recent years due to political uncertainty and limited public and donor investment. Construction activities picked up once again in preparation for the 2015 African Games and as a result of the 'Municipalisation Accélérée' programme, which consists of selecting one city each year to be the beneficiary of construction projects to develop roads, schools, dams, hospitals and airports.

Private projects continue in Kinshasa with the development of residential areas, retail and business centres, and hotels. Funding is always a major problem.

Numerous major projects have been planned for many years, as shown in Table 4, but funding or conditions of contract remain a constraint. Considering the agri-parks, the Inga Hydro Scheme and rail upgrades alone, funding of some US$11 billion will be required.

Housing

The shortage of housing is well recognised. There is uninterrupted growth of shanties around the major urban centres on abandoned land (land subject to erosion, hillside slippage and flooding) in which the vulnerable population is concentrated. Improving

Table 4: Major projects being planned

Energy
Busanga hydroelectric plant (240 MW) and networks
Inga III hydro scheme
Kanke hydroelectric plant (300 MW) and networks
Katende hydroelectric plant (64 MW) and networks
Kolwesi–Solwesi Interconnector (Zambia/DRC)
Luapula hydroelectric plant (600 MW) and Kolwezi-Solwezi power lines
Methane gas power plant at Lake Kivu (30 MW) and networks
Ruzizi 3 (147 MW) hydroelectric plant and networks
Sicomines hydropower plant
Wania-Rukula hydroelectric plant (700 MW) and networks
Water
Congo Basin water transfer project from the DRC to Angola, Botswana, Namibia, Zambia and Zimbabwe
Kasumbalesa cross-border water supply and sanitation project between the DRC and Zambia
Roads & Rail
Rehabilitation of port infrastructure in Matadi
Upgrading of 130 km of the Dulia-Bomdo Road
Upgrading of 140 km of the Kalemi–Kambu Road
Rehabilitation of 2 400 km of SNCC rail infrastructure, stations and purchasing of rolling stock
Mining and Industry
Sicomines copper and cobalt mine
Kamoa-Kupfervorkommen copper mine
Development of agro-industrial parks

town planning and ensuring that new areas are serviced for development is essential.

To overcome the shortage and poor quality of housing, in 2006 the World Bank advocated restructuring of the housing sector and the development of new sites; the drafting of legal and regulatory provisions on leasing; the creation of a housing bank and introduction of a system of bank credit for housing promoters and real estate developers, etc.; and the development of sufficient housing to meet the Millennium Development Goals 7 by 2030. Sadly, little has happened in relation to low-cost housing.

LOCAL GOVERNMENT

It is difficult to gain an understanding of local government, as from all accounts there are no engineers employed in municipalities. A press article confirms this when it says, *'the Congolese government runs a country where municipal services of any kind are the exception rather than the rule'*. National departments tend to provide all consumer services – SNEL provides electricity and REGIDISO water and sanitation services. Wastewater treatment is by all accounts a challenge. As a result, treatment works are non-functional, or overflow. This was funded for many years through a European Union programme which ended some three to four years ago. The OVD takes care of urban roads and the DVDA takes care of rural roads. Municipal buildings are provided by the Ministère des Infrastructures, Travaux Publics et Reconstruction (MITPR). Parks, sports and recreation areas are often developed and secured by employers, except for national sports complexes which are developed and secured by the Ministère de la Jeunesse, Sport et Loisir. Other municipal services have suffered neglect over the years, including parks and cemeteries, which are often unsafe to use, as captured in the documentary, *Cemetery State.*

EDUCATION, TRAINING AND PROFESSIONAL DEVELOPMENT

Education and training is a vital part of developing engineering capacity. All elements, from teaching appropriate subjects in schools to continuing professional development (CPD), need to be in place to educate and train engineering personnel and ensure that they remain abreast of the latest technology, challenges and emerging solutions.

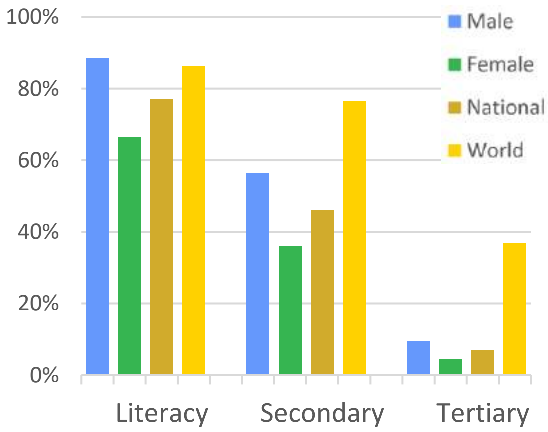


Figure 9: Literacy and enrolment statistics
(UNESCO from 2013 to 2016)

PRIMARY AND SECONDARY EDUCATION

Academic education in the DRC takes 12 years to complete, of which the first six are free, and lead to a *certificat d'etudes primaires*. This is necessary to proceed on to secondary education. Unfortunately, many students, especially in rural areas, fail to get this far. Secondary education (which may be either general or technical) takes a further five years, at the conclusion of which they receive a *brevet* certificate.

Limited numbers finally complete secondary education for many reasons, including affordability, travel logistics and conflict.

The quality of education also presents a challenge. Although 93% of primary school teachers are qualified, only 17% of secondary school teachers are said to be qualified and trained to teach. School infrastructure is also in a state of disrepair and classroom conditions are inadequate, with lack of desks, textbooks and equipment presenting further challenges.

VOCATIONAL EDUCATION

Students may go from primary school to vocational education instead of following an academic secondary education programme. In vocational education students can follow programmes that last six years in various trades and crafts, after which they are awarded a *diplôme d'etat* and may enter industry as qualified artisans. They are considered to be technicians in the DRC.

HIGHER EDUCATION

There are many privately and publicly funded universities, polytechnics and specialised colleges, but for many years there were only a few state universities including the Universities of Kinshasa, Lubumbashi and Kisangani and a handful of Institutes of Technology, the main ones being the Institut des Bâtiments et Travaux Publics (IBTP) and the Institut Supérieur de Techniques Appliquées (ISTA).

The government authorised the introduction of private higher education in the 1990s. Considering the diversification philosophy enshrined in the constitution of 2005, it was decided that each of the 26 provinces should have its own university, to bring higher education closer to the population and ensure that ethnic groups were given equal opportunities.

In August 2017 a report from the Ministry of Higher and University Education on private institutions indicated that there were:

- 64 existing accredited institutions
- 113 that had applied for accreditation
- 16 that had been provisionally accredited
- 160 newly established institutions that had been given permission to operate but had not yet applied for accreditation
- 35 that were established and had been inspected, so could start operating
- 183 established and awaiting inspection before they could start operating.

This made a total 571 private higher education institutions. There are also 405 public institutions.

The government contributes less than 40% of the higher education bill, relying on student fees, research and donations to cover the balance of the costs. However, as part of the SSEF the government is offering scholarships for females wishing to study engineering. The African Development Bank (AfDB) also offers bursaries for students to study in the DRC.

The proliferation of institutions has meant that the budget is insufficient and there are too few academics to resource each institution adequately. Some institutions report staffing vacancies to be as high as 80%. As a result, experienced academics are expected to lecture at more than one institution, often great distances apart. This rarely happens, but rather senior academics in established institutions send their final year and post-graduate students to deliver lectures, few of whom have had any practical experience or adequate knowledge to offer more than a regurgitation of what they were taught. Few are equipped to prepare lectures or have had any training in class management and teaching. The result is poor-quality graduates from many institutions, who have difficulty in finding work.

Furthermore, in many institutions there are limited or no laboratory facilities and in the long-established institutions, equipment is often obsolete. In some cases, lecture hall capacity is limited and some students stand outside to listen to lectures. The government has recognised the need to re-equip institutions and train academics, including offering support for PhD studies, as part of the Education Project for the Quality and Relevance of Teachings at the Secondary and University Levels (PEQPESU), but funding is limited.

University engineering degrees are structured in three phases: a preparatory year equivalent to a foundation year in many other countries; three years of scientific, mathematical and general engineering theory; followed by two years of advanced theory relating to the chosen discipline. Students graduate as engineers and their qualification is known as *Ingénieur Civil* followed by the discipline, e.g. a mechanical engineer would qualify as an *Ingénieur Civil Mécanicien* (engineer qualifications are referred to as IR2 in Table 5). Universities also offer a five-year qualification which is composed of three years of theory and two years of applied subjects from which students graduate as *Ingénieur Industriel* (referred to as II2 in Table 5). The theory is not as rigorous as in the six-year qualification and these graduates are equivalent to technologists in other countries.

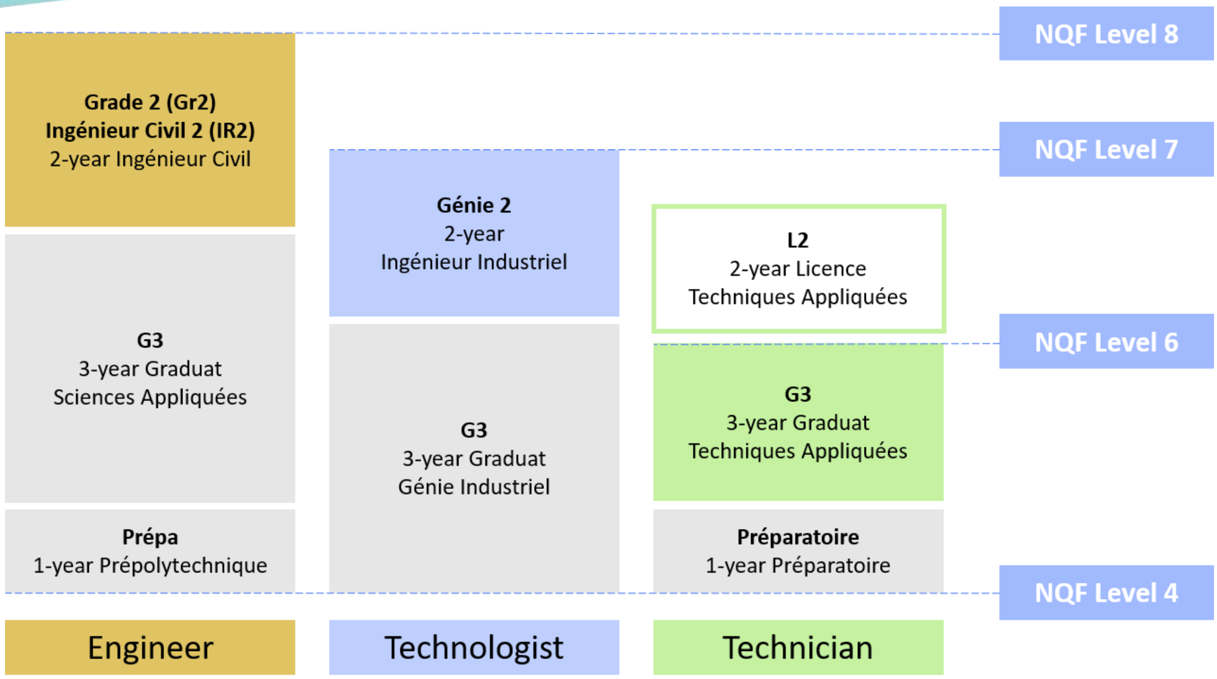


Figure 10: Engineering qualification levels compared with the South African NQF levels

(Courtesy: Dr Francois Mulenga, Associate Professor, Mining Engineering, UNISA)

There are now many ISTAs which offer more practically orientated qualifications. The qualifications are also offered over six years: a preparatory year; three years of applied theory, after which a student may graduate with a certificate reading *Gradué en Techniques Appliquées* (referred to as G3 in Table 5); followed by two years of more advanced theory, after which a student will graduate with a *Licencié en Techniques Appliquées* (referred to as L2 in Table 5). The three-year qualification is equivalent to a technician qualification and the five-year qualification is slightly less rigorous than technologist qualifications offered in the region. The technologist is known as an *Ingénieur Technicien,* followed by the discipline.

Considering the credits earned, the extent of mathematics and science subjects, the complexity of subjects and project work, the level of each qualification is compared with the South African NQF levels in Figure 10.

The L2 qualification is essentially a post-graduate qualification, which is offered part-time by many institutions. Only about 20% complete L2 full-time after G3. The balance enters the workforce after G3 and they are encouraged to complete L2 part-time before being considered for promotion.

Universities have started to integrate the Bologna process or LMD system into their teaching to allow students to be able to move around and earn credits at institutions applying the Bologna system. According to an engineering professor at the University of Kinshasa, the World Bank has made funding available to institutions to investigate and migrate to this system. The Catholic University of Congo (UCC) based in Kinshasa was one of the first to complete the transition in 2013.

Responses from most government departments and large manufacturing companies indicate that technical staff in their employ are from the largest and longest established universities and institutes of technology. As there are too many graduates for the current investment and development levels, graduates struggle to find work. It is estimated that some 50% completing university degrees leave the country to complete post-graduate courses, after which few return.

The institutions graduating engineering students are shown in Table 5. Only a few of the major institutions were able to offer historical data, but the Ministry of Higher and University Education has been gathering information since the 2013–2014 year and was able to provide some graduation details, generally only for selected years from most institutions. The year for which the most substantial data was received per institution is shown in Table 5. The totals may therefore be overstated, as the numbers graduating vary considerably from year to year. Many institutions graduate limited numbers of engineering students, in some cases only three to five per discipline per year. An average of graduate numbers received from 2013 to 2017 has been used for the projection under the *Numbers and Needs* section.

Several institutions listed by the Ministry as offering engineering qualifications did not submit graduation data. Furthermore, new private institutions are still coming on stream and have just commenced or plan to commence offering engineering qualifications, but it was not possible to determine numbers likely to graduate in the future. Institutions offering engineering qualifications from which graduate data was not available are listed in Table 6.

More detailed graduate data made available by certain institutions has been combined and is shown in Figure 11. The trend of graduations increasing over time is clear to see.

The Institut National du Bâtiment et des Travaux Publics (INBTP) and several Institut des Bâtiments et Travaux Publics (IBTP) focus on the construction sector.

Although hundreds of technicians and technologists are reported to graduate from these institutions, the numbers in Table 5 refer to only those completing civil engineering courses and do not include graduates in town planning, GIS, architecture and construction management.

The largest discipline in terms of graduate engineers is agriculture. The University of Yangambi is the largest institution, graduating 150 to 200 each year. Many dedicated agricultural institutions offer agronomy qualifications. Known as Institut Supérieur d'Études Agronomiques (ISEA) (listed in Table 7), most offer three-year qualifications and their graduates are known as agricultural engineering technicians. The largest two are Benga Misa and Mondongo.

Table 5: Engineering graduations in the DRC in 2013/2017
*(*IR2 = engineer, L2 or II = technologist, G3 = technician)*

INSTITUTION	YEAR	QUALIFICATION	Aeronautical	Agriculture	BTP	Chemical	Civil	Electrical & Electronic	ICT	Mechanical	Metallurgy	Mining
Public institutions												
Institut des Bâtiments et Travaux Publics de Butembo (IBTP)	2013	G3			89							
Institut des Bâtiments et Travaux Publics de Kisangani (IBTP)	2016	G3			350							
Institut des Bâtiments et Travaux Publics de Matadi (IBTP)	2017	G3			87							
Institut national du Bâtiment et de Travaux Publics de Kinshasa (INBTP)	2017	G3					111					
Institut national du Bâtiment et de Travaux Publics de Kinshasa (INBTP)	2017	L2					157					
Institut Supérieur de Techniques Appliquées de Burhuza (ISTA)	2017	G3						5			14	8
Institut Supérieur de Techniques Appliquées de Domiongo (ISTA)	2017	G3						13	3	3		
Institut Supérieur de Techniques Appliquées de Ebonda (ISTA)	2015	G3						37				
Institut Supérieur de Techniques Appliquées de Goma (ISTA)	2015	G3						75		53		
Institut Supérieur de Techniques Appliquées de Goma (ISTA)	2013	L2						7		20		
Institut Supérieur de Techniques Appliquées de Gombe Matadi (ISTA)	2014	G3						87				
Institut Supérieur de Techniques Appliquées de Kasangulu (ISTA)	2016	G3						86				
Institut Supérieur de Techniques Appliquées de Kinshasa (ISTA)	2013	G3	40					957		697		
Institut Supérieur de Techniques Appliquées de Kinshasa (ISTA)	2014	L2	6					13	149	91		
Institut Supérieur de Techniques Appliquées de Kolwezi (ISTA)	2013	G3				44		16		15		29

Table 5: Engineering graduations in the DRC in 2013/2017
*(*IR2 = engineer, L2 or II = technologist, G3 = technician)*

INSTITUTION	YEAR	QUALIFICATION	Aeronautical	Agriculture	BTP	Chemical	Civil	Electrical & Electronic	ICT	Mechanical	Metallurgy	Mining
Public institutions												
Institut Supérieur de Techniques Appliquées de Lubumbashi (ISTA)	2014	G3						96			62	56
Institut Supérieur de Techniques Appliquées de Matadi (ISTA)	2013	G3								18		
Institut Supérieur de Techniques Appliquées de Ndoluma-Lubero (ISTA)	2017	G3						6		4		
Université de Bandundu (UNIBAN)	2017	IR2		13								
Université de Bunia (UNIBUN)	2015	IR2		24								
Université de Goma (UNIGOMA)	2015	IR2		71								
Université de Kamina (UNIKAM)	2016	IR2		13						15	23	24
Université de Kikwit (UNIKIK)	2014	IR2		33								
Université de Kinshasa (UNIKIN)	2017	IR2		104			61	36		18		
Université de Yangambi	2017	IR2		~200								
Université de Kolwezi (UNIKOL)	2014	IR2		23							29	25
Université de l'Uélé (UNIUELE)	2017	IR2		8								
Université de Likasi (UNILI)	2015	IR2										152
Université de Lubumbashi (UNILU)	2017	IR2		83						15	23	24
Université de Malemba Nkulu (UNIMALEMBA)	2016	IR2		12								
Université de Mbuji-Mayi (UM)	2013	IR2		5								
Université de Ruwenzori (UNIRU)	2017	II						2	2			
Université de Semiliki De Beni (UNISEM)	2016	IR2		19								
Université Président Joseph Kasa–Vubu	2016	IR2		4								1
Private institutions												
Institut du Pétrole et du Gaz (IPG)	2015	G3				71						
Institut du Pétrole et du Gaz (IPG)	2017	L2				27						
Institut Supérieur de Gestion et des	2015	G3						4	22			3
Institut Supérieur des Techniques Appliquées	2016	G3						4				
Institut Supérieur Technique (IST) de Boma	2016	G3				24						
Institut Supérieur Techniques d'Informatique	2015	G3							33	17		
Institut Supérieur Techniques d'Informatique	2015	L2							3	5		
Université Adventiste de Lukanga (UNILUK)	2017	IR2		4								
Université Catholique de Bukavu (UCB)	2016	IR2		48								
Université Catholique du Graben (UCG)	2015	IR2		46								
Université Kongo (UK)	2017	IR2		8						15		
Université Libre de Luozi (ULL)	2016	IR2		4								
Université Libre des Grands Lacs (ULGL)	2017	IR2		42								
TOTAL												
Engineers – University (1225)		IR2		764			61	36		63	75	226
Technologists – University (4)		II						2	2			
Technologists – IST (478)		L2	6			27	157	20	152	116		
Technicians – IST (3239) + ISEA (400)		G3	40		526	139	111	1386	58	807	76	96

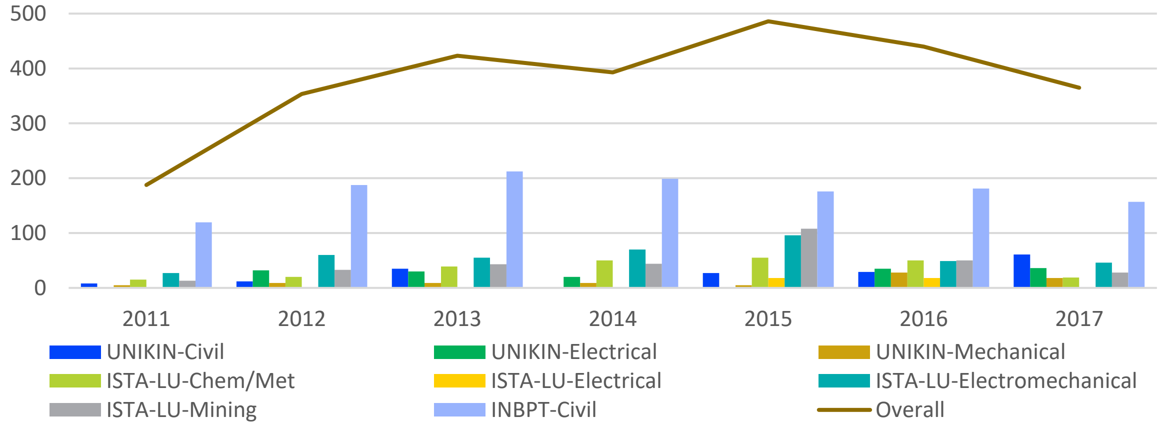


Figure 11: Graduations from UNIKIN, ISTA Lubumbashi and INBPT

Table 6: Institutions from which engineering graduation data was not available

INSTITUTION	
Public institutions	**Private institutions**
Institut des Bâtiments et Travaux Publics de Butembo (IBTP)	Institut Supérieur de Gestion et des
Institut des Bâtiments et Travaux Publics de Kisangani (IBTP)	Institut Supérieur des Techniques Appliquées
Institut des Bâtiments et Travaux Publics de Matadi (IBTP)	Institut Supérieur d'Etudes Techniques
Institut Supérieur de Techniques Appliquées de Burhuza (ISTA)	Institut Supérieur d'Etudes Techniques
Institut Supérieur de Techniques Appliquées de Domiongo (ISTA)	Institut Supérieur Technique (IST) de Boma
Institut Supérieur de Techniques Appliquées de Ebonda (ISTA)	Université Chrétienne Bilingue au Congo (UCBC)
Institut Supérieur de Techniques Appliquées de Gombe Matadi (ISTA)	Université Evangélique en Afrique (UEA)
InstitutSupérieur de Techniques Appliquées de Kasangulu (ISTA)	Université libre des Pays des Grands Lacs (ULGL)
Institut Supérieur de Techniques Appliquées de Kolwezi (ISTA)	Université Loyola (UL)
Institut Supérieur de Techniques Appliquées de Matadi (ISTA)	Université Protestante de Kimpese (UPK)
InstitutSupérieur de Techniques Appliquées de Ndoluma-Lubero (ISTA)	Université Simon Kimbangu (USK)
Université de Kela (UNIKELA)	
Université de Lomami (UNILOMAMI)	

The early years of all agricultural qualifications cover agricultural science, mathematics and problem-solving. In the final years, students specialise in one of several areas, including plant or livestock technology; forestry and water, or soil and water; environmental engineering and natural resources; or marketing management, among others. Some institutions also offer veterinary qualifications (ISEAV) and others also offer forestry (ISEAVF). Graduates who follow veterinary programmes are not classified as engineers or engineering technicians. Limited graduation data was available for the ISEAs, but from the data available, it appears that small numbers graduate per institution each year. The total number of agricultural technicians graduating is approximately 300 to 400 each year, plus a small number of technologists. Graduation statistics from engineering faculties at universities offering agricultural engineering qualifications are shown in Table 5.

Table 7: List of Instituts Supérieur d'Études Agronomique (ISEA)

INSTITUTION	
ISEA Basoko	ISEA Mvuazi
ISEA Benga Misa	ISEA Omendjadi
ISEA Bokonzi	ISEA Tshela
ISEA Kenge	ISEA Untu De Kamponde
ISEA Kimbau	ISEA Zomfi
ISEA Kiyaka	ISEAV Aru
ISEA Laba	ISEAV Lukashayi
ISEA Lodja	ISEAV Maniema
ISEA Loeka	ISEAV Mushweshwe
ISEA Lomela	ISEAV Sandoa
ISEA Mangai	ISEAV Walungu
ISEA Mondongo	ISEAVF Butembo
ISEA Mukongo	ISEAVF Kirumba

Accreditation

The Ministry of Higher and University Education accredits institutions but does not consider detailed requirements per qualification. Professional bodies are not formally requested to assist in the accreditation process but, in the case of the main universities, input is considered from industry from time to time.

Student mobility

In 2015, there was a total of 3 577 Congolese studying at South African universities, 745 of whom were studying by correspondence, through the University of South Africa. The highest attendance was at the Cape Peninsula University of Technology, with 782 enrolled, followed by the University of Johannesburg and the Vaal University of Technology, with 643 and 520 enrolled respectively.

A total of 182 engineering students graduated, 15 with degrees, 50 with BTechs and 117 with national diplomas. The number graduating in South Africa has been increasing steadily year-on-year, starting from a low base of nine in 2005. Numbers graduating in other countries and returning were not readily available.

Post-graduate studies outside the country are encouraged and funded by many companies to develop specialists. France and Japan appear to be the most common destinations for post-graduate study.

GRADUATE TRAINING

Once the tertiary education phase is complete, it is necessary for graduates to receive structured training in the workplace, under professional supervision and mentorship, to develop to the level of competence required for professional registration, and to be able to take on work independently. Apart from structured training being offered by a few of the larger organisations and utilities, little support is offered in the training of graduates. Those graduating who are unable to get suitable training opportunities either remain unemployed, open their own small businesses, go into other sectors or may find employment outside the country.

PROFESSIONAL REGISTRATION

Until December 2018, there was no system for the registration of engineering professionals. This meant that there were no mechanisms for dealing with shoddy work or barring engineers from practising if their work was unsafe or of a questionable standard. After years of lobbying, the National Order of Civil Engineers (*L'Ordre National des Ingénieurs Civils* (ONICIV)) was promulgated on 13 December 2018 which requires that a council be set up by March 2019. Much development work will be required to put a system in place, but this is a major step forward for the engineering profession in the country.

VOLUNTARY ASSOCIATIONS AND CONTINUING PROFESSIONAL DEVELOPMENT (CPD)

Although there has been no registering body, there are several voluntary associations representing the interests of engineering in the DRC. The Congolese Association of Civil Engineers (*Association Congolaise des Ingénieurs Civils* (ACIC)) was initiated under Presidential order No. 90-165 of 8 August 1990. It is a non-profit professional association whose purpose is to contribute to industrialisation of the country and to develop engineers by understanding the issues that affect them and assisting members in their careers.

The term 'civil' in the name of the organisation refers to non-military or civilian. The ACIC represents engineers across the range of engineering disciplines, including chemical, civil, electrical, mechanical, metallurgical and mining. Their membership is limited to those with six-year university qualifications from universities which they believe produce graduates at the level of mastery expected of an engineer. There are those which they believe are not up to standard, largely as a result of a lack of academics and other resources. The ACIC can therefore be considered as informally accrediting engineering degrees in the country.

Since the 1960s some 3 500 to 4 000 engineers have graduated in the traditional disciplines of chemical, civil, electrical, mechanical, mining and metallurgy. Of these it is estimated that about 2 000 to 3 000 still practise in the country. The ACIC currently has just under 500 members. Part of its mission is to offer CPD and develop relationships and exchanges between members, associations of foreign engineers and other corporate associations.

A smaller body, the DRC Engineers Organisation (*Organisation des Ingénieurs de la Republique Democratique du Congo* (OIC)), was formed to represent a smaller number of young engineers.

The Association of Agricultural Engineers of the Congo (*L'Association des Ingénieurs Agronomes du Congo* (ASSIAC)) is a non-profit organisation established in 1990, based in Kinshasa, which supports the development of Congolese agricultural engineers and the Association of Agricultural Engineering Technicians of the Congo (*L'Association des Ingénieurs Techniciens Agronomes du Congo* (ASSITAC)) supports its agricultural engineering technician members.

Each association has a Code of Conduct according to which it expects its members to perform and will play some form of regulatory role should unacceptable behaviour or malpractice be identified.

Chapters of international bodies such as the South African Institute of Mining and Metallurgy (SAIMM) and the international Institute of Electrical and Electronic Engineering (IEEE) have also been formed.

An interesting body, the Association of Engineers of DRC Origin in South Africa (AEDOSA), has been formed in South Africa to contribute to the industrialisation process of both the DRC and South Africa and to look after the career development and advancement of its members.

WOMEN IN ENGINEERING

Although there does not appear to be a women's chapter linked to any of the associations, a separate organisation, the Women's Technology Association (Wotech), made headlines when they decided to address the traffic challenges and particularly the high fatalities on Kinshasa's roads. They designed a robot, known as Robocop, which videos traffic behaviour and transmits footage to the police to deter drivers from breaking road regulations. Five Robocops are now installed in Kinshasa; they are each 2.5 m high, are made of aluminium, weigh 250 kg and are each powered by a solar panel.

Figure 12: A RoboCop in action in Kinshasa

THE WORKFORCE

According to estimates by practitioners in the country, there are some 10 000 to 12 000 engineering practitioners in the workforce in traditional engineering disciplines, made up of up to 2 000 to 3 000 engineers, the balance being technologists and technicians. This could not be verified. A further 7 000 to 8 000 agricultural engineers, technologists and technicians make up the total engineering workforce.

THE PRIVATE SECTOR

The main employers in the private sector are consulting, contracting, manufacturing, supplier and mining companies. Lower numbers are employed in small entrepreneurial companies, training organisations and other companies where engineering input is required, as well as many NGOs assisting with social infrastructure, rural development and enhancing farming methods.

Consulting

There do not appear to be any bodies representing the interests of consulting engineers in the DRC. There are some 20 to 30 consulting engineering companies locally, most of which are branch offices of international companies.

The managers are generally Congolese who were educated in the DRC and spent time out of the country gaining experience and working in branches or even the head office of their current employer before returning to manage local branches. In the Katanga province, given the emphasis on mining, most foreign owned offices are branch offices of Zambian or South African consultants.

Few offices remain in place for long periods. Consulting firms bid for projects and only open a small branch once they are awarded a project of a certain amount and close once the project is over. These short-term offices would be composed of three to five staff and they may also use engineers resident in the DRC as subconsultants if additional capacity is required. There are also many local engineers working on their own as consultants who employ other engineers if and when they receive an appointment.

There are also many international consultants who do not have a presence in the DRC, but carry out designs externally and send staff to discuss matters with clients or oversee construction from time to time. In the absence of detailed research, it is estimated that a total of 300 to 400 consulting engineering practitioners are based in the country.

Contracting

Contractors must be licensed by the MITPR before they can be awarded a public sector project. In September 2018, 286 companies were registered. Licences are granted for a three-year period. They are classified by size into four categories, A to D where A is the largest. As with consultants, contractors appear to come and go depending on the opportunities. Only 13% of those registered had been registered prior to 2015 and only 4% had been registered prior to 2010, although registration has been in place since 1999.

With regard to local contractors, some 72 contracting companies belong to the Federation of Congolese Enterprises (FEC). However, given that contracting requires significant capital for machinery and equipment, the larger contactors have substantial foreign ownership, with Chinese, South African and European construction firms having been major players for many years. It is estimated that the large influx of Chinese firms has led to a situation in which they now manage more than 90% of the public and private construction projects. The smaller local contractors are generally only used as subcontractors by the big companies, or for small or simple projects.

The construction industry's contribution to economic growth has reduced significantly in recent years due to the drop in commodity prices in 2015 and 2016. Despite this, in March 2016, the infrastructure ministry identified over US$6 billion worth of transportation and utilities-related infrastructure projects for construction or rehabilitation over the next six years.

Manufacturing

Some 200 agro-processing and manufacturing companies belong to the FEC. The large companies employ many engineers and hundreds of technicians. From the limited returns received it would seem that there are over 5 000 engineering practitioners in the sector, the most widely used being mechanical and electrical engineers. The FEC is both the Chamber of Commerce and Industry, and the main employers' organisation. In addition, the Confederation of Small and Medium Enterprises of Congo (COPEMECO) represent the interests of small companies.

Mining

Returns submitted to the Extractive Industries Transparency Initiative (EITI) by 87 mines reflected employment figures of just over 50 000, with a further 30 000 in the employ of subcontractors. Considering employment and mining output statistics in Zambia, it has been estimated that some 1 000 engineers and technicians would be employed in the mining sector in the DRC. The Chamber of Mines represents the interests of mining companies.

Agriculture

Due to the dependence on agriculture, agricultural engineers play a key role in the private sector, the government, in research and in the employ of NGOs. In 2018, about 800 agronomic engineers belonged to the ASIAC. It is estimated that there are about 6 000 agricultural engineers in the country in total. About 750 agricultural engineers graduate per year.

Agricultural engineers in the private sector work for commercial farms (of which there are few), suppliers or NGOs, or have their own farms or small businesses consulting to smallholders. They may be involved in breeding, production, fisheries and water resource management. They focus on planning and designing techniques and technologies to increase production and improve productivity.

The potential to develop the agricultural sector is great, but few take the initiative to raise funding for, and develop, innovative solutions. Many agricultural engineers in the private sector therefore report working in, or owning, businesses in other sectors.

Currently, it is estimated that about 1 700 agricultural engineers and 1 800 agricultural engineering technicians work in government. It is thought that the majority of agricultural engineering technicians work in government, with some 320 belonging to the ASSITAC. Considering those who have moved into other sectors suggests that no more than 2 000 work in engineering in the private sector.

THE PUBLIC SECTOR

Many engineering practitioners are required in the public sector to plan new services, issue project tenders and oversee the delivery of, and operate and maintain, infrastructure. Table 8 shows the departments that are the main employers of engineering skills.

Lack of staffing and budgets, however, present a problem. The utilities advised of 25% vacancies, the ministries have an average of 40% vacancies in technical posts, and the provincial structures, which are responsible for provincial and municipal infrastructure, have very few technical staff. The challenge throughout appears to be the level of remuneration, lack of budget to fill posts and critical projects not being prioritised and receiving budget. In some instances, this even results in the existing limited number of staff finding themselves with little to do.

Table 8: Ministries employing engineering practitioners

MINISTRY/STRUCTURE
Ministry of Agriculture (Ministère de l'Agriculture)
Ministry of Cooperation & Development (Ministère de Coopération au Développement)
Ministry of Energy & Hydraulic Resources (Ministère de l'Energie et Ressources Hydrauliques) • National Electricity Company – SNEL (Société Nationale d'Electricté) • Water Distribution Board – REGIDESO (Régie de Distribution d'Eau)
Ministry of the Environment & Sustainable Development (Ministère de l'Environnement et Développement durable)
Ministry of Fisheries & Livestock (Ministère de Pêche et Elevage)
Ministry of Health (Ministère de la Santé)
Ministry of Higher & University Education (Ministère de l'Enseignement Supérieur et Universitaire)
Ministry of Hydrocarbons (Ministère des Hydrocarbures)
Ministry of Industry (Ministère de l'Industrie)
Ministry of Infrastructure, Public Works & Reconstruction – MITPR (Ministère des Infrastructures, Travaux publics et Reconstruction) • National Roads Authority – OdR (Office National des Routes) • Roads and Urban Drainage Authority –OVD (Office des Voiries et Drainage)
Ministry of Mines (Ministère de Mines)
Ministry of National Defence, Former Fighters & Reintegration (Ministère de la Défense Nationale, des Anciens Combattants et de la Réinsertion)
Ministry of Planning (Ministère de Plan)
Ministry of Posts, Telecommunications & New Information & Communications Technologies (Ministère des Postes, Télécommunications et Nouvelles Technologies de l'Information et de la Communication) • Congolese Posts & Telecommunications Company – SCPT (Société Congolaise des Postes et Telecommunications) • Congolese National Radio and Television– RTNC (Radio-Télévision Nationale Congolaise)
Ministry of Primary, Secondary& Professional Education (Ministère de l'Enseignement Primaire, Secondaire et Professionnel)
Ministry of Professional Training, Jobs &Handicrafts (Ministère de Formation Professionnelle, Métier et Artisanat)
Ministry of Rural Development (Ministère du Développement Rural) • Department of Agricultural Services – DVDA (Direction des Voies de Desserte Agricole)
Ministry of Scientific Research (Ministère de Recherche Scientifique)
Ministry of Transportation & Communication (Ministère de Transport et Communication) • National Transport & Ports Company – SCTP (Société Congolaise de Transports et Ports) • National Railways Company of Congo – SNCC (Société Nationale des Chemins de Fer du Congo) • Matadi-Kinshasa Railways – CFMK (Chemins de Fer Matadi-Kinshasa) • DRC Airways – RVA (Régie des Voies Aériennes de la République Démocratique du Congo) • Civil Aviation Authority – AACI (Autorité de l'Aviation Civile)
Ministry of Urbanisation & Habitat (Ministère de l'Urbanisme et Habitat)
Ministry of the Interior and Security (Ministère de l'Intérieur et Sécurité)

Table 8: Ministries employing engineering practitioners

The majority of agricultural engineering practitioners are employed in the Ministries of Agriculture, Rural Development or Industry, while others are employed in fisheries and environmental development, and smaller numbers in education, defence and water, among others.

In the Ministry of Agriculture their main role is to advise and support farmers, but given the large number of farms, there are simply not enough employed to cover the need. Limited budgets constrain the support they can offer and in rural development limited budgets constrain the roll-out of infrastructure. Many are employed in the Ministry of Industry to monitor and control the quality of imported food.

MIGRATION TRENDS

Analysis of the United Nations Population Division statistics for 2015 shows a net loss of capacity from the DRC. Of those entering the country, 32% were from each of Rwanda and the Central Africa Republic. Twenty-four percent of emigrants moved to Uganda, 17% to Rwanda and a further 13% to Burundi. These figures appear to relate largely to labour and not professionals, and refer only to those who officially emigrated or immigrated.

There is ongoing movement of engineering professionals as projects are awarded to international companies. During 2018, with the political uncertainty and slowdown of the economy, many expatriates were leaving the country and contracts were not being renewed. The number of Congolese engineers living outside the country is also unknown. Several hundred belong to the AEDOSA in South Africa, and a further 700 or so are studying in the country, many of whom plan to remain and work in South Africa upon graduation.

ENGINEERING NUMBERS AND NEEDS

Due to limited survey returns, particularly from the private sector, an accurate employment model could not be developed. Table 9 therefore represents a very rough estimate of the distribution of engineering skills, but should be read with caution.

It should be noted that the number refers to those working in engineering and not in the workforce in general, as it appears that many move into other sectors due to lack of opportunities in engineering.

Considering the need to rehabilitate, expand services, fill vacant posts and grow the economy, there is clearly a need for qualified and well-experienced engineering practitioners. However, appointing any more would be foolhardy until such time as adequate investment has been made in infrastructure and the development of the local manufacturing sector. As outlined earlier, manufacturing companies are withdrawing from the DRC and mining operations are even being curtailed in certain areas.

Using the Ministry data, the average number of engineers to graduate over the reporting period was 1 176, including agricultural engineers from Yangambi. Some 2 500 technicians qualified, including 526 BTP graduates. Only a small percentage of the technologist graduate figures is included as most technologists study part time and would have already been counted as entering the workforce after graduating as technicians.

Table 9: Estimated numbers of engineering practitioners in the engineering workforce

SECTOR	ESTIMATED NUMBER
Academia and research	800
Agriculture	2 000
Consulting	400
Contracting	1 000
Government	5 000
ICT, systems and telecommunications	1 000
Manufacturers and suppliers	5 000
Mining	1 000
Miscellaneous and NGOs	1 800
TOTAL	**18 000**

Figure 13 shows the current workforce, the losses that will occur over the 18-year period to 2035 due to retirement, mobility and mortality, and the growth in engineering capacity if engineering graduations increase at 2% per year over the period.

The blue dotted line shows the growth in skills that would be required at the 2017 GDP growth rate of 3.4%, and the green dotted line shows the growth based on the 2018–2023 GDP projection of 4.3%. A 70% employment elasticity factor has been used to extrapolate the employment demand.*[1]

The number graduating far exceeds the demand at the projected growth rate but will also exceed the Agenda 2063 projection, if this was to be reached. It appears that graduations are far too high. As a result, engineers seek post-graduate opportunities outside the country. It is estimated that at least 50% leave after graduating, hence the Graduate Engineers Emigrated label in Figure 13.

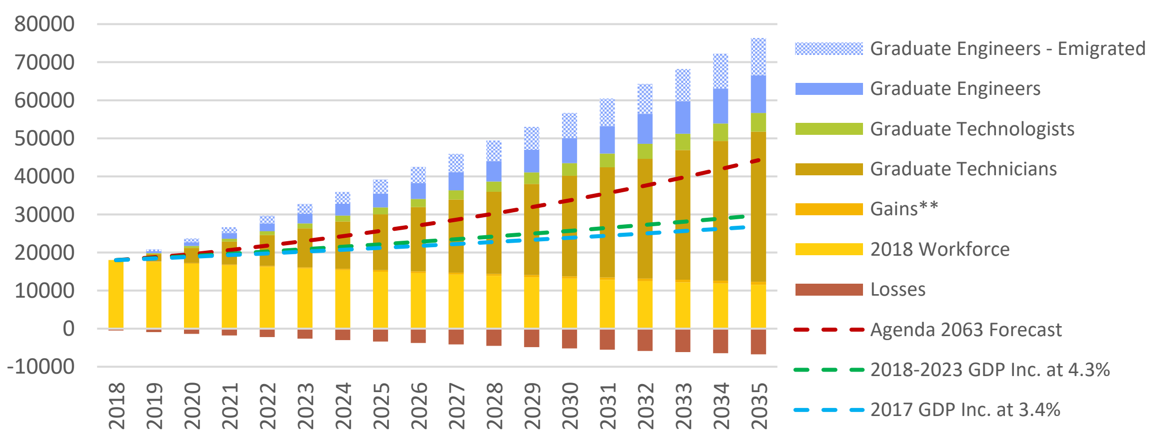


Figure 13: Flow of engineering skills based on 2% graduation rate increase per year

***Excludes international engineering practitioners in the country on short-term contracts*

*[1] Employment elasticity is a measure of the percentage change in employment associated with a 1% change in economic growth. If the growth is likely to be in agriculture, the percentage could be lower, as growth in that sector generally has to do with productivity gains and not employment, while if the growth is likely to be in high-tech manufacturing, the elasticity factor may be more than 100%.

The mismatch can also be attributed to an underestimate of the number in the engineering workforce, although, given the economic conditions, it is unlikely that there would be 40 000 to 50 000 in the workforce, which is of the order required to absorb and train the numbers graduating.

The proliferation of institutions offering engineering qualifications should be rationalised, so that investment can be focused on the stronger institutions able to offer quality education.

The benefit of increased numbers will not be realised unless graduates coming into the system are supervised and coached by experienced practitioners to be able to take over from the older cohort and the expatriate community which currently carries out much of the engineering workload. It is critical that a national programme for graduate training, development and succession planning is put in place.

It should also be noted that the gains shown represent gains made by formal immigration or those returning to the engineering workplace after an absence. Should large numbers of engineering practitioners enter the country as part of international contracts, or due to placement by their international offices, these gains will have a greater impact on the inflow of skills shown and there will be less vacancies for graduates to fill in the workforce.

When reviewing the adjustments which should be made in higher education, it should be noted that in terms of the traditional engineering disciplines, the number of civil and electrical engineers graduating at 60 and 37 respectively is low. If these numbers are indeed correct, then more learners should be encouraged to become engineers in these disciplines. Due to the incompleteness of the data, it is suggested that the DRC mount a major campaign to develop a comprehensive database of all enrolments and graduations for purposes of planning a tertiary education programme qualification mix.

KEY RECOMMENDATIONS

To develop a sound pool of engineering professionals, able to contribute to the well-being of the DRC, the following should be considered:

Schooling

- **Primary and secondary education:** Address the weaknesses in primary and secondary education, and increase the number completing secondary education with acceptable results.
- **Career guidance:** Expand career guidance to attract high-calibre entrants into the engineering profession, incorporating programmes to reach female learners, and rural and low-income areas.
- **Bursaries:** Provide bursaries to attract those who excel in mathematics and science to study engineering.

Higher education

- **Consolidation:** Consolidate engineering studies into well-resourced universities and institutes to ensure quality output.
- **Accreditation:** Develop a rigorous national accreditation programme in collaboration with professional bodies to ensure the quality of engineering education using the guidelines of the Washington, Sydney and Dublin Accords or alternatively, consider using the accreditation guidelines of the European Network for Accreditation of Engineering Education (ENAEE) and support universities and institutes to be able to work towards achieving the chosen accreditation requirements.
    - Encourage institutions to develop adequate complex engineering problem-solving content and graduate attributes to satisfy the requirements of the Washington, Sydney and Dublin Accords.
    - Create awareness of accredited qualifications and warn learners of those that will not lead to registration as engineering professionals.
    - Withdraw qualifications which do not meet accreditation requirements.
- **Industry liaison:** Liaise with industry on a regular basis to ensure that curricula, methods, software and equipment are relevant and up to date.
- **Curricula:** Provide funding to research, modernise or develop curricula and material where required.
- **Facilities:** Raise funding to upgrade lecture theatres, libraries and laboratory facilities where required.
- **Resources:** Raise funding for computers, engineering software, access to online reference material, and laboratory equipment, and ensure adequate support to offer technology-relevant training.
- **Attract and retain academics:** Improve conditions of service, support and packages to attract, retain and appoint additional academics.
- **Teaching methods:** Apply the latest methods and technology for teaching, and train academics in 21st century approaches to teaching.

- **Academic development:** Provide funding for lecturer post-graduate development and facilitate opportunities for academics to gain experience in industry.

Graduate training

- **Develop programmes:** Develop national graduate training programmes to ensure graduates achieve the level of competence required by industry and for professional registration.
- **Private sector incentives:** Offer incentives for private sector companies to develop graduates.
- **Public sector support:** Ensure that public sector structures take on and train graduates and that they are absorbed and developed through the ranks.
- **Institutional support:** Institutionalise graduate training in all organisations by setting KPIs for experienced staff to act as supervisors and mentors.
- **Project support:** Make graduate training a requirement of all public sector projects and ensure that the progress of graduates is monitored, and penalties are imposed for non-compliance.

Registration of engineering professionals

- **Registration development:** Support the set up the new council, regulations and systems to implement the requirements of the new National Order of Civil Engineers.
- **VAs:** Recognise and support the development of voluntary associations in the engineering sector.

Continuing development

- **CPD:** Support the development of a robust CPD system rolled out by the various voluntary associations and higher education institutions, to include courses, workshops, conferences, online learning etc.
- **Validation:** Validate short courses and skills programmes for a specified period only to ensure that training remains up to date and relevant.
- **Post-graduate studies:** Provide post-graduate bursaries to develop specialists.
- **Develop managers and leaders:** Encourage industry to continue investing in graduates after professional registration to grow management and leadership capabilities.

Registration of service providers

- **Expand licensing conditions:** The Ministry of Infrastructure, Public Works & Reconstruction should consider adding further requirements into the licensing conditions for construction contractors. They should be expanded to:
  - Cover the increasing use of local consultants, contractors, labour, plant and materials.
  - Ensure that foreign consultants and contractors partner with local companies.
  - Ensure that there are requirements for consultants and contractors to train graduates, artisans and other construction-related skills.
  - Ensure that local contractors are developed as part of large projects.
  - Ensure that international consultants provide all calculations, drawings, operating manuals and other reference material in French.
  - Ensure that local consultants, along with the client, check that design proposals address local needs and customs and that design calculations comply with national codes and standards.
  - Limit companies to a certain size or category of work based on their technical skills, past experience and the availability of plant and capital.
- **Quality:** Implement quality assurance and ensure penalties are imposed for poor performance.

The public sector

- **Economic infrastructure:** Invest in the development of economic infrastructure such as electricity, roads, rail, ports and airports, and address the supply of water services.
- **Maintenance:** Invest in maintenance to preserve new infrastructure and prevent further deterioration of existing infrastructure.
- **Tariffs and payment:** Review and increase tariffs where appropriate, and enhance domestic revenue collection and demand management to fund development.
- **Technical capacity:** Reprioritise budgets to build technical capacity, ensure that salaries are competitive and develop succession plans to make the public sector an employer of choice.
- **Technical decision-makers:** Ensure that engineers are employed in senior decision-making posts.
- **Procurement:** Review procurement conditions to ring-fence more work for local consultants and contractors.
- **Contractor support:** Promote, and subsidise if necessary, local contracting companies to acquire plant and construction equipment.

Industry-wide collaboration

- **Advisory team:** Set up an engineering advisory team, recognised by government, to advise on and endorse infrastructure development proposals, tertiary curricula and graduate training programmes.
- **Collaboration:** Encourage all professional bodies to work together to share knowledge, exchange best practice and ensure coordinated planning of industry support initiatives.

ACKNOWLEDGEMENTS

The detailed picture presented would not have been possible without the help of the South African Embassy in Kinshasa, the Ministry of Higher and University Education and the support of academics, various professional bodies, many government departments and many passionate engineers. A big thank you to Louisa Buthelezi and Vanessa Kasongo for setting up all the appointments and assisting with research meetings. Thanks go to academics Profs Paul Tshiula from the University of Kinshasa, Ilunga Mutombo from the University of Lubumbashi and Antoine Nzeza from INBPT for insights and graduation data.

Thank you also to Charles Medard and Jean Bernard Tshiasuma of the ACIC for data gathered and education and industry insights. A big thank you to Coco Kabongo and Tartibu Asani for always being willing to assist and offering lots of input, and to Ms Mira Mboma, journalist at Television 50 DRC, for the huge support and guidance throughout the process. The support and input from members of OEDOSA in South Africa must be mentioned, including from Drs Kany Kabeya, Estime Mukandila, Ilunga Tshimbidi and Prof. Francois Mulenga. There were many others from both the private and public sectors who contributed data and views – thank you to you all.

SOURCES OF INFORMATION

Data and information were gathered during meetings, interviews and telephone conversations, and via email. SADC reports, master plans and strategies as listed under *Plans and Strategies,* and many standard international sets of data as listed in Chapter 5, *Research Approach,* were also consulted. Further information was gathered from PageWeb Congo, *Engineering News*, *Mining Weekly* and *World Folio*. Comprehensive documents focusing on specific issues in the DRC as listed below were additional sources of information.

Baharanyi, N., Karki, L.B. and Mutaleb, M. 2014. *Democratic Republic of the Congo: AET background study*. Alabama: Tuskegee University.

Foster, V and Benitez, D.A. 2015. *The Democratic Republic of Congo's infrastructure. A continental perspective*. (*Africa Infrastructure Country Diagnostic)*). Washington, DC: World Bank.

Ministère de l'Enseignement Supérieur et Universitaire. 2017. *Etat des Lieux des Etablissements Prives de l'Enseignement Supérieur et Universitaire Reconnus.* Kinshasa.

Ministère de l'Enseignement Supérieur et Universitaire. 2018. *Etablissements Publics de l'Eau par Territoire*. Kinshasa.

Ministère du Plan et Suivi de la Mise en oeuvre de la Révolution de la Modernité. National Agency for the Promotion of Investments. 2015. *Major Projects Awaiting Funding*. Kinshasa.

Mwamayi, A., Wood, G., Haines, R. and Brookes, M. 2015. Exploration of the Democratic Republic of Congo (DRC) textile industry survival: Case of La Société Textile de Kisangani (SOTEXKI). *African Journal of Business Management*, 6(19): 6037–6051.

REC (Repertoires des Entreprises Commerciales, Industrielles et de Services). 2017. *Annuaire 2017.* Kinshasa.

Trefon, T. 2016. *Congo's Environmental Paradox: Potential and Predation in a Land of Plenty*. London: Zed Books.

ESWATINI

ESWATINI, officially the Kingdom of Eswatini, is the second-smallest country in Africa by size and population. Just over 1.3 million people live in this landlocked country which is almost enclosed by South Africa but is bounded by Mozambique to the east.

Eswatini is blessed with mineral resources and abundant water supplies, recording one of the highest annual precipitation rates in the SADC region. This lends itself to agricultural output.

Sadly, Eswatini has recorded the world's highest HIV/AIDS prevalence rate along with the highest incidence of TB for several years. In 2017, the HIV prevalence rate was estimated at around 18%. Eighty per cent of TB patients are co-infected with HIV. Medical treatment makes severe demands on the fiscus and has resulted in a generation of orphans, with the older ones finding themselves raising their younger siblings. The country also has one of the highest unemployment rates in the region and 42% live below the international poverty line.

Mbabane is the administrative capital and Manzini the commercial hub. The two cities and the corridor between them support approximately 75% of the country's urban population. Growth in both Manzini and Mbabane has been largely informal and about 60% of urban households live in unplanned and/or un-serviced informal settlements.

THE ECONOMY

Eswatini's economy is based on free market principles. The benefits are enjoyed by the growing urban population, but the majority of the population support themselves through subsistence farming on rural homesteads.

Although the largest contributor to the GDP is manufacturing, the non-engineering services sectors, including wholesale and retail trade, financial, real estate, business and other services, have contributed around 50% of the GDP since 2009, dropping from 61% in 2000.

The economy suffers volatility due to the ravages of climate change giving rise to extreme droughts or floods. Because of its small size, it relies heavily on the export sector, composed primarily of large firms with predominantly foreign ownership.

Eswatini boasted one of the world's fastest-growing economies until the early 2000s, but with the economic recession and questionable labour practices, the country has fallen foul of some of the terms of the African Growth and Opportunity Act (AGOA). This has limited its export potential and growth has dropped from some 7% in the heydays to less than 1% in 2017. The situation is exacerbated by what many feel is excessive expenditure by the Royal Family.

PLANS AND STRATEGIES

There are several important plans and development policies in place, the most important of which are:

- **His Majesty's Vision 2022** in which His Majesty King Mswati III has a vision of seeing Eswatini become a First World nation by 2022, founded on sustainable economic development, social justice and political stability.
- **The National Development Strategy 2022** aimed at eradicating poverty by creating an attractive investment climate, based on sound macro-economic policies and fiscal discipline. The

Table 1: Eswatini metrics

Population	
Total	1 146 000
Urban	23.3%
Rural	76.7%
Poverty, HIV, Unemployment	
Below the international poverty line	42.0%
HIV-positive	18.3%
Unemployment	28.1%
Human Development Index	0.531
Electricity	
Production kWh	381m
Consumption kWh	1.43bn
Airports and Ports	
Airports	14
- Paved	2
- Unpaved	12
Kilometres of Services	
Roads	3 594
- Paved	1 078
- Unpaved	2 516
Rail	301
Africa Infrastructure Development Index	25.76
Access to Services	
Access to safe drinking water	74%
- Urban	94%
- Rural	69%
Access to improved sanitation	68%
- Urban	95%
- Rural	61%
Access to electricity	27%
- Urban	40%
- Rural	24%
Telephones	42 000
Mobile phones	995 000
Internet users	29%

strategy recognises the importance of social developments, safe water and sanitation, the efficient utilisation of natural resources, the development of infrastructure and human capital, research and innovation.

- **The Programme of Action (2013–2018)** which outlines the steps that each ministry will take, through service delivery, to address economic prosperity, agricultural and environmental sustainability, education, health, infrastructure, governance and corruption.
- **The Private Sector Development Strategy** aimed at creating jobs, addressing inclusiveness and economic development. The infrastructure goal seeks to improve transport infrastructure and logistics services through Public-Private Partnerships (PPPs), with a special focus on developing feeder roads to move agricultural and other products efficiently around the country.
- **Swaziland Transport Master Plan (STMP) (2013–2032)** which outlines the plans to enhance road, rail and air transport.

In early 2018, the King changed the name of the country from Swaziland to Eswatini, which means 'land of the Swazis' to avoid confusion with the country name of Switzerland. Many companies have started to change their company name to reflect the new country name, but not all have made this move. The name change is, however, being contested as unconstitutional.

ENGINEERING ACTIVITIES

Figure 1 shows the contribution of engineering-related economic activities to the country's GDP. By far the largest sector is manufacturing, followed by agriculture. Considering each in turn will give a picture of the activities, trends, challenges and opportunities for the engineering profession to contribute to the Eswatini's growth.

AGRICULTURE

Dual agricultural sectors are represented by largely rainfed subsistence farmers living on Swazi National Land (SNL) and large private estates.

Subsistence farming

Subsistence farmers constitute 70% of the population and occupy 75% of the arable land, but productivity is low, accounting for only 11% of total agricultural outputs. Erratic availability of water for irrigation is a major constraint to smallholder production, and in years of low rainfall, harvests plummet, giving rise to food shortages and the need to import. Most Swazi households grow rainfed maize and vegetables, and few have diversified to add cash crops to their planting. As a result, few families depend solely on what they can grow but have an absentee wage earner working on one of the commercial farms or in South Africa. Cattle ownership is high, with the ratio of cattle to land being among the highest in Africa.

Cattle can graze on common pasture, and government dipping and veterinary services are generally provided without charge. The ease of owning cattle has led to overgrazing and land degradation, undermining the sustainability of many smallholdings.

Considering smallholder vulnerability to climate change, developing irrigation systems is vital for increasing and sustaining productivity and for keeping farmers on the land, rather than moving to urban areas which are unable to support them. Poor access roads and links to markets must be addressed.

In His Majesty's Government Programme of Action, targets have been set for raising the production of maize to 140 000 MT by 2018 and to 160 000 MT by 2022. This will require a local seed-production programme, and input assistance for farmers. Such

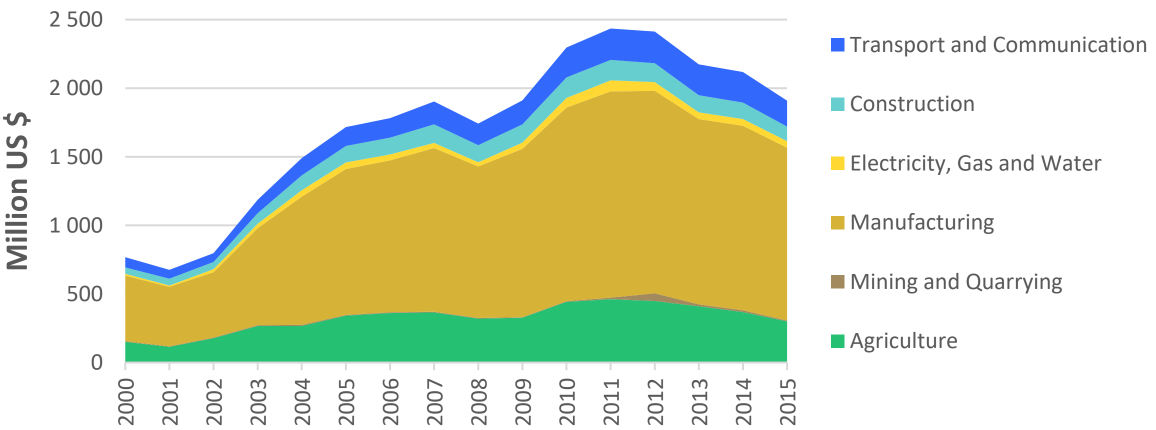


Figure 1: GDP per engineering-related economic activity (52% of the GDP)

assistance will include increasing the number of tractor hire service centres from 18 to 50 by 2018, which involves the acquisition of a further 100 tractors.

Commercial farming

The commercial agriculture sector is dominated by sugar, fruit for canning and beef production for export. Citrus and pineapples are other important crops. The commercial sector relies heavily on irrigation, with some 95% of water withdrawals being for irrigation.

Sugar is the largest single foreign exchange earner, and is exported to the EU, the USA, Mozambique and South Africa. Sugar is also sold to the manufacturing sector, particularly to the soft drink, confectionery and jam-making industries. In 2016, there were 523 sugarcane growers registered with the Swaziland Cane Growers Association, 488 of whom were smallholders.

Citrus is exported to the EU, Eastern Europe and the Middle and Far East. Spoilt fruit is sold to canning factories and large quantities of pineapples are also canned and sold in Europe, along with fruit juices.

Forestry

Pine and eucalyptus plantations cover 4% of the country and employ 17% of the formal labour force. The Usutu pine forest is one of the largest man-made forests in the world. The trees are principally grown and exported for wood pulp although timber is also used by the mining and construction industries. The forests contribute some 14% of export revenues.

MINING AND QUARRYING

Eswatini's natural resources include coal, iron-ore, asbestos, diamond and gold deposits, talc and quarry stones. The coal deposits are high-quality and may be used for industrial applications.

In 2017 fewer than 1 000 Swazis were employed in the mining industry, and the only active mine was the Maloma Colliery, with the underground operations producing some 40 000 tons/month. The only iron ore mine was closed in 2014 due to the decline in ore prices.

There are plans to extract 2 million metric tons of iron ore concentrate by reworking the tailings of the Ngwenya Iron Ore Mine (the mine itself was closed in 1977). Gold extraction from the north-western region, which is an extension of the Barberton (South Africa) goldfield, is planned, with the Piggs Peak Mine to be revived. More sites have been prospected for extraction with a view to growing the mining sector. Plans are also in place to revive the Dvokolwako Mine, with diamond production expected to achieve a yield of 80 000 carats per year.

The government is working towards minerals contributing 4% to the GDP by 2018 with the help of the private sector. Twenty students have been sent to Taiwan to study for mining-related qualifications.

MANUFACTURING

The many and diverse manufacturing and processing concerns are predominately private sector enterprises and range from small home-based entrepreneurs to large factories employing hundreds of people and utilising the latest technology. The categories of goods produced include food and beverages; clothing and textiles; timber, pulp and paper; engineering and metal industries; plastics and chemicals. The split of manufacturing value add is shown in Figure 3.

Figure 2: Mhlume Sugar Mill, Royal Swazi Sugar Corporation (RSSC)
(Courtesy: RSSC)

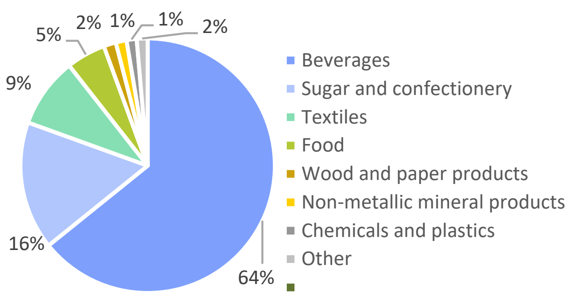


Figure 3: Manufacturing value add per subsector
(Central Statistics Office, 2016)

Food and beverages

The diversification of sugar products is at the heart of manufacturing. Coca-Cola Swaziland (Conco Ltd) and the Cadbury Schweppes Group produce soft drink concentrates that are exported throughout Africa and to the UK and Australia. Other products relying on the availability of sugar include jellies, glacé fruit and canned fruit; Cadburys Swaziland produce a wide range of sweets. The major lines are Choclairs and Chappies, which are widely exported.

Another important line of products, based on the availability of fruit and sugar, is the canning of pineapples and other fruit and juice concentrates. A major earner of foreign exchange, these products are sold to the UK, Germany, Spain, Italy, Portugal, the USA and Japan.

Flour, animal feed, fresh and long-life milk, yoghurt and *emasi* are other food products that are manufactured.

Textiles and clothing

Clothing and textiles, including fashion items, knitwear, uniforms, protective overalls, zippers and yarns, are important by value, but contain large components of fabric imports. They are generally low-tech. There is a ginnery in Big Bend which produces cotton lint. Yarns are also produced locally.

Timber, pulp, paper and packaging

Commodities produced include unbleached kraft pulp, furniture and fittings in kit and finished form, construction materials, pallets, corrugated board, other forms of packaging, and various types of paper.

Plastics, chemicals and other non-metallic mineral products

Plastic products for industrial and domestic applications, including packaging film and PVC electrical conduits, are manufactured, but most plastic products are imported from South Africa.

Local brands of soaps, detergents and other cleaning materials are manufactured for local consumption, but name brand products are generally imported, as are fertilisers and pesticides.

PPC commenced cement production in 2012, and a range of blocks, bricks, pavers, precast culverts, pipes and related building materials are manufactured locally.

Pharmaceuticals

The country relies heavily on imports for medicines and medical supplies, with limited local production capacity. The Swaziland Pharmaceutical Strategic Plan (2012–2016) aims at increasing local production through offering incentives and creating an enabling environment.

Metal industries, machinery and equipment

Commodities include industrial gases, medical gases and related regulators and equipment. Important gases include carbon dioxide for the manufacture of carbonated drinks. Arc welding machines, robotics and plasma cutters are also important for use in the heavy industrial sector.

Other products manufactured include refrigerators and their components, borehole pumps, steel fencing, tubing and related items, and steel and wire goods for the construction industry.

ELECTRICITY, GAS AND WATER

Electricity

Eswatini has the third-smallest total electricity production of the SADC countries. It produces about 20 to 25% of its electricity, with the balance coming from South Africa and Mozambique. In 2013, it was estimated that a total of 27% of households had access to electricity, made up of 40% in urban areas and 24% in rural areas.

Around 80% of the electricity generated comes from Eskom and the balance from Swaziland Electricity Corporation (SEC) and independent power producers (IPPs) supplying to the grid. The Corporation, a parastatal under the Ministry of Natural Resources and Energy (MNRE), manages all energy supply in Eswatini and was renamed the Eswatini Electricity Corporation (EEC) in mid-2018.

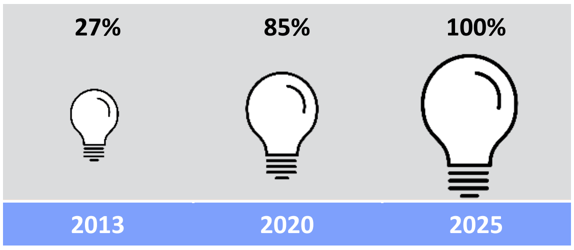


Figure 4: Target dates for access to electricity

EEC owns and operates hydropower plants which contribute 60.1 MW to the grid, and diesel generators which supply 9.5 MW. The volume of hydropower fluctuates depending on water levels, hence production reduces during times of drought.

Since 2011, Ubombo has been supplying power to the grid through the use of bagasse. Eswatini has set renewable energy targets, including the installation of solar water heaters in 20% of all public buildings. The country also has potential for renewable energy production from wind and solar. Less than half of those with access to electricity use it for cooking – the majority still use wood, while 11% use gas. Rural electrification is a priority.

The need to increase local generation capacity and reduce reliance on neighbouring states is recognised and EEC is looking at many options. As Eswatini has major coal reserves, the development of a 1 000 MW coal-fired power station is under consideration. In addition, feasibility studies are being carried out for hydropower plants on several sites along the Ngwempisi and Lower Maguduza Rivers. The MNRE has also committed funds to develop the Lubovane Dam hydro generation project.

Oil and gas

Eswatini has no known oil or natural gas reserves and all gas and oil is imported and distributed by major companies such as BP, Caltex, Galp Energia and Engen.

Water and sanitation

A total of 74% of the population had access to safe drinking water, made up of 96% of the urban population, and 63% of the rural population in 2015 and some 68% of the population had access to improved sanitation.

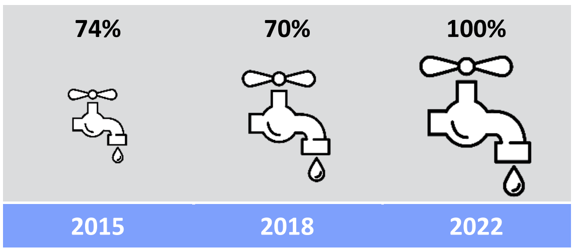


Figure 5: Target dates for access to safe drinking water

Water and sanitation services to the urban areas are provided by the Eswatini Water Services Corporation (EWSC) and to the rural areas by the Department of Water Affairs. However, since 2017 EWSC has been assisting the Department to fast-track water services to ensure that the target of universal access is achieved by 2022.

Eswatini has nine major dams, seven used for irrigation, one for hydroelectricity and one for water supply. Users withdraw almost double the volume of water available in the dams from wells and rivers. To ensure water security, address the risks associated with climate change and provide drinking water to urban areas feasibility studies are underway for a multi-purpose dam on a tributary of the Lusushwana River.

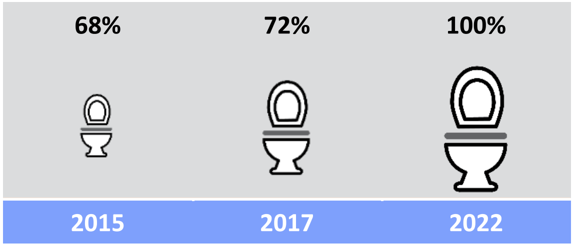


Figure 6: Target dates for access to improved sanitation

Many rural water schemes are also being planned or are underway to improve irrigation from rivers and wells to address water-security challenges for rural communities.

TRANSPORT AND COMMUNICATION

Roads

Eswatini has a classified road network of about 3 594 km, 30% of which is paved. Sixty per cent of the paved network is in good condition and the country enjoys well-developed road links with South Africa. National and district roads are maintained by the Ministry of Public Works and Transport (MOPWT) and municipal roads by each municipality.

Over the years, there has been significant funding for improving the main road network, but there has been limited investment in district roads and the condition of many is poor. This increases road user costs and impedes public transport, limiting socio-economic development in rural areas.

Several road upgrades are underway, including upgrading of the Piggs Peak to Bulembu road from gravel to an asphalt surface. This will link Eswatini to Barberton and Nelspruit in South Africa. Plans are also in place to upgrade the Mbabane to Manzini Highway to six lanes. Substantial national and district road upgrades have been earmarked in the Transport Master Plan covering the period 2013 to 2032, many of which are listed in Table 2 under *Construction*.

Rail

Swazi Rail operates some 300 km of railway lines that run from east to west, making it possible to export bulk goods through the Port of Maputo in Mozambique, and north to south, providing a connection to Mpumalanga and the ports of Richards Bay and Durban in South Africa.

The Swaziland Rail Link development, which will consist of a 150 km of new railway line from Lothair in South Africa to Sidvokodvo in Eswatini and the revamping of two existing lines in both countries, will shorten travel time between the two countries and will increase transit freight through the country. The new line, designed to carry 200 general freight wagons at a time and with a capacity of 12 trains per day, will be operated as a seamless service without stopping at any of the borders either into or out of Eswatini.

Airports

The only international airport is the King Mswati III International Airport which was constructed to replace the Matsapha Airport. It came into service in 2014 and is capable of servicing 300 000 passengers, but the demand for air travel has been limited to flights from Manzini to OR Tambo (ORT) International in Johannesburg. Negotiations are underway to expand tourist routes to Durban, Cape Town and Harare in Zimbabwe. A complement of aircraft and aviation engineers, technicians and mechanics have been trained to service the airport and airline.

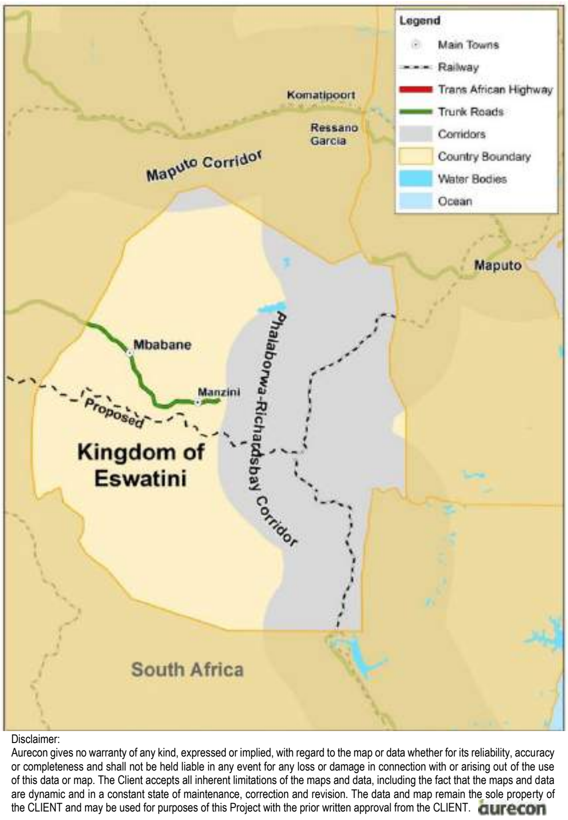


Figure 7: Transport corridors

Communications

The service sector, which is one of the fastest growing sectors, relies on good telecommunications. Mobile market penetration is well above the average for the region. Being landlocked, the country depends on neighbouring countries for international fibre bandwidth. Through connections to South Africa and Mozambique, Eswatini has connectivity to the submarine fibre cables, namely SEACOM and EASSy in Mozambique, and ten existing and in-development cables through South Africa.

However, the infrastructure within Eswatini was controlled by the Eswatini Post and Telecommunications Corporation (EPTC), which limited the opportunity to develop and improve the backbone through privatised investment. MTN and Swazi Mobile have since entered the market but prices are still high.

Eswatini has both digital microwave and fibre links to South Africa (from Mbabane to Johannesburg). It is also party to the Motraco (power utility in Mozambique) fibre cable linking Mozambique, Eswatini and South Africa, which is owned by the power companies of the three countries.

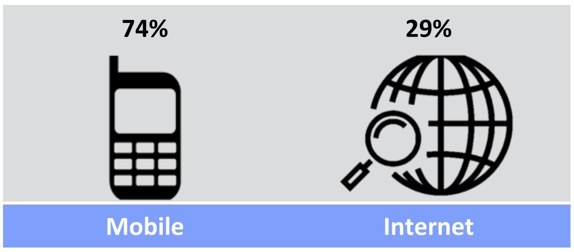


Figure 8: Percentage of population connected to services

Mobile coverage is largely well developed along main roads and within towns, with 4G/LTE being available in Mbabane and Manzini. This means that mobile connectivity is the primary medium for both voice and internet connectivity. As of 2016, there were 995 000 mobile device subscriptions, representing 74% penetration. There are 42 000 fixed-line telephones subscribers, providing for just 3% of the population.

There are seven internet service providers but the cost of internet access is still very high, with 1 GB of mobile bandwidth costing $US35 in 2017, the most expensive of all the SADC countries. This explains why only 29% of the population has internet connectivity. As a fixed line is required for ADSL connectivity, only 0.5% of the population make use of this technology to connect to the internet. Satellite internet connections are available, but they are extremely expensive.

ESWATINI

CONSTRUCTION

Construction is important in any country due to its ability to create jobs and develop skills. The construction industry employs some 16 000 people. From 2000 to 2012, the construction industry's contribution to the GDP grew rapidly and efforts were made to increase the number of local contractors. Historically, the sector was dominated by foreign companies, which implies that part of the revenue earned did not remain in the country. Sadly, the industry is still heavily reliant on government-funded projects, which can only go ahead if funding is secured. Due to the country's reducing liquidity, construction has slowed down since 2016.

Major road developments are planned, to improve mobility, along with the mining, energy and water projects described above, as shown in Table 2. The challenge is the flow of funding.

Housing

In support of Vision 2022 to provide sustainable home ownership through affordable housing solutions, the Swaziland National Housing Board delivers housing solutions to lower and middle-income earners. In addition, it provides rental units at affordable local rates within the densely populated urban areas and has handed over numerous plots on title deed land for development by Swazi citizens. The Human Settlements Authority was formed by the government to address the challenge of informal housing, but little progress has been made.

LOCAL GOVERNMENT

There are 13 declared urban areas – comprising two city councils, four town councils and seven town boards – and 55 *tinkhundla* (regional areas managed by elected members from the regional communities). Electricity and water is supplied to local government by the utilities, including the treatment of wastewater. Municipalities are responsible for town planning,
housing, roads, regulation of water and sanitation, refuse collection and disposal, street and traffic lights, environmental protection, parks and open spaces, cemeteries and other public amenities.

EDUCATION, TRAINING AND PROFESSIONAL DEVELOPMENT

Education and training is a vital part of developing engineering capacity. All elements, from teaching appropriate subjects at schools, to continuing professional development, need to be in place to educate, train and ensure that engineering personnel remain abreast of the latest technology, challenges and emerging solutions.

PRIMARY AND SECONDARY EDUCATION

Primary education is from Grade 1 to Grade 7 and secondary education spans five-years divided into three years in junior secondary school and two years in senior secondary school. Education at secondary level is neither compulsory nor free. Only 50% of those who complete primary education continue to junior secondary level, representing about 20 000 learners, and around 30% continue to senior secondary level. Of concern is the fact that only 13.5% finish the secondary cycle.

A study by the Southern and Eastern Africa Consortium for Monitoring Educational Quality (SACMEQ) conducted in the early 2000s found that the quality of basic education in Eswatini was not up to standard, with both reading and mathematics scores of Swazi sixth-graders being much lower than those achieved by students from Kenya and Tanzania, whose GDP per capita was much lower than that of Eswatini at the time.

At secondary level, the most distinctive issue was the lack of mathematics and science teachers. It was found that, on average, there was one mathematics

Table 2: Major projects identified, or being planned or under construction

PROJECT		VALUE US$	START YEAR	END YEAR
Energy	New coal-fired power station	$970m	Being negotiated	
Water	Lomahasha/Namaacha Cross-Border Water Supply Project between Mozambique and Eswatini	$13.5m	Seeking funding	
Roads & Rail	Bulembu-Piggs Peak Road MR 20		Seeking finance	
	Improvement of MR103 from Ezulwini to Matsapha	$53.7m	2018	2022
	Improvement of MR18 from Bhunya to Nokwan	$80.3m	2018	2022
	Improvement of MR3 from Mbabane to Manzini	$91.6m	2023	2032
	Lukhula Big Bend Road-MR 16		Seeking finance	
	Nhlangano-Sicunusa Road	$38.3m	2014	2017
	Upgrading of second priority District Roads	$51.1m	2018	2022
	Upgrading of third priority District Roads	$61.9m	2023	2032
	Swazi-SA rail link to open new coal capacity	$1.67bn	2014	2019
Other	Development of gold and coal mining		TBD	

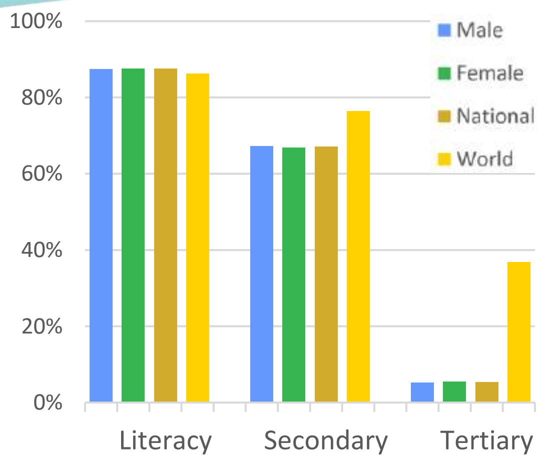


Figure 9: Literacy and enrolment statistics
(UNESCO from 2013 to 2015)

teacher for every 84 secondary school learners. The pass rates in mathematics are very low and present a challenge to feeding the needs of engineering, the sciences, medicine and financial qualifications. Learners at private schools perform significantly better than their counterparts at government schools.

TERTIARY EDUCATION

There are only two institutions that offer engineering qualifications in Eswatini, as shown in Table 3. The University of Botswana and Swaziland was the forerunner of the current university. Students would complete the first two years of their degree in Eswatini and the final two years in Botswana. The university was established as two separate entities in 1982.

The only engineering degrees on offer are Agricultural and Biosystems Engineering (formerly known as Agricultural Engineering) and Electrical and Electronic Engineering.

The Department of Agricultural and Biosystems Engineering has seven academic staff who are responsible for teaching, research and executing community mandates of the University of Eswatini (UNESWA). The Bachelor of Science in Agricultural and Biosystems Engineering programme is the only undergraduate programme offered by the department.

Concern has been raised by agricultural engineering academics from countries in the region that there is not enough mathematics and engineering problem-solving in the curriculum for the qualification to be considered as an agricultural engineering degree.

The Department of Electrical and Electronic Engineering offers a five-year bachelor's degree which is focused largely on electronics and systems rather than on heavy power engineering. Modules include:

- Electrical Machines
- Electronic Communication Systems
- Computer Engineering and Embedded Systems
- Industrial, instrumentation and process control systems
- Signal Processing and embedded controllers
- Mechatronic Systems.

The content does not adequately serve the needs of the power sector. The Eswatini College of Technology (ESCOT) offers a range of qualifications in engineering and the built environment, but only four engineering qualifications are offered at diploma level. They are diplomas in civil, electrical, mechanical and automotive engineering. These qualifications are, however, not recognised by the Engineering Council of South Africa to be equivalent to Dublin Accord qualifications, so applicants need to apply using the Alternative Route, which takes the qualification and experience into account, should they wish to apply for professional registration as technicians in South Africa.

Contractors employing local diplomates complained that they were not able to handle construction supervision and could only be used for site inspections; consultants complained that they could not handle basic design and could generally only be used for draughting and detailing; and others complained that they could not be used for maintenance management. Employers suggested that the level of problem-solving that students are exposed to during their studies is inadequate. The number graduating each year is very variable.

ESCOT needs to determine the actual number required, limit class sizes and focus on increased complexity, problem-solving and addressing industry needs.

An MOU exists between ESCOT and the Vaal University of Technology in South Africa to assist with strengthening the qualifications on offer and, similarly, there is an MOU between UNESWA and the Tshwane University of Technology.

The graduation statistics are shown in Table 3 and the split by gender, category and discipline is shown in Figure 11. Only recent data was received from both institutions, although these qualifications have been on offer for many years.

ESWATINI

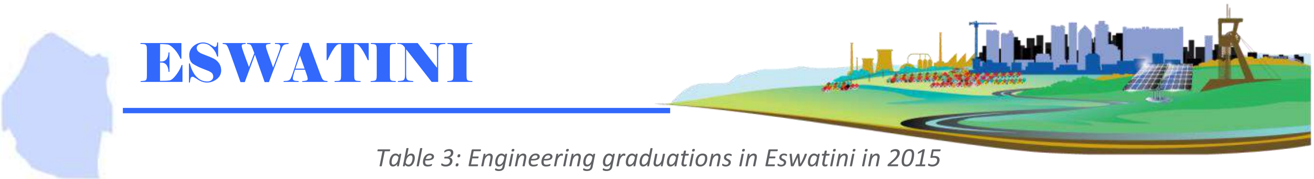


Table 3: Engineering graduations in Eswatini in 2015

INSTITUTION	QUALIFICATION	Start year	Agricultural Biosystems	Civil	Electrical & Electronics	Mechanical	Telecommuni-cations
University of Eswatini (UNESWA)	BSc(Eng)	1982	31	-	108	-	
Eswatini College of Technology (ESCOT)	N Dip	1946	-	53	24	21	29
TOTAL							
Engineer (139)			31	-	108	-	
Technician (127)			-	53	24	21	29

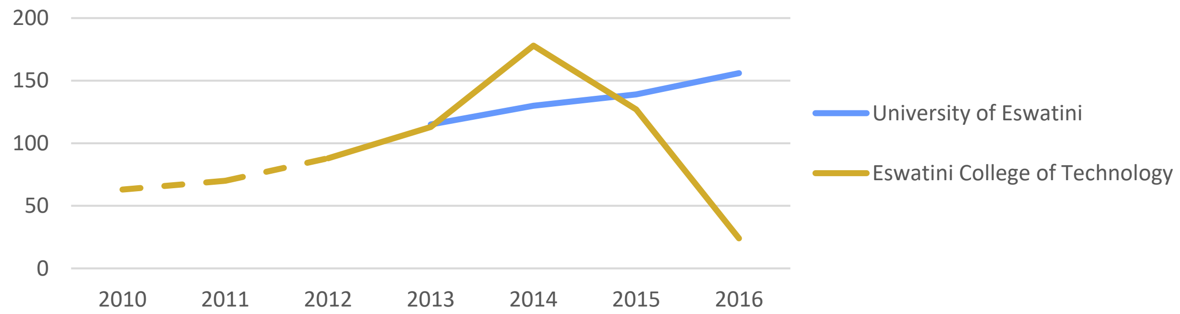


Figure 10: Engineering graduates by institution

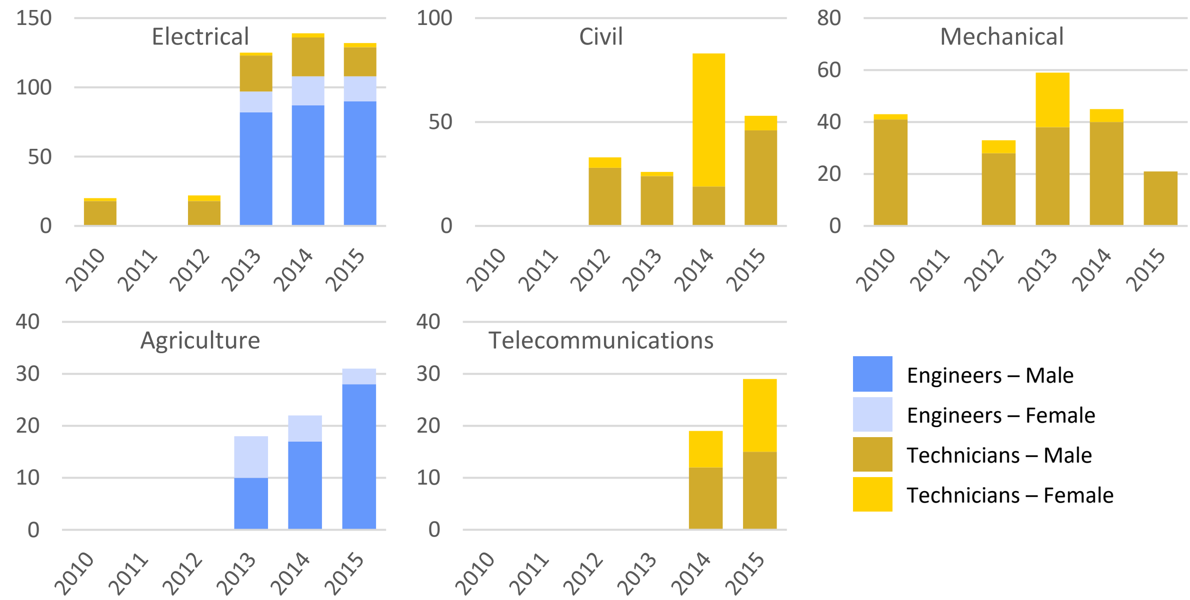


Figure 11: Engineering graduates by discipline, category and gender

Accreditation

There does not appear to be any formal accreditation process for any of these qualifications. Although, in time, the region should be working towards the standards set by the International Engineering Alliance (IEA), it is suggested that at present input be sought from curriculum specialists, able to advise on the structuring and content of the engineering qualifications, to ensure that they better address industry needs. Once the registration council, the Architects, Engineers, Surveyors and Allied Professionals Registration Council (AESAP), is fully functional, this responsibility should fall to them.

Student mobility

Given the lack of tertiary education opportunities in Eswatini, Swazis wishing to study engineering need to study outside the country. In times past, Swazis generally received funding from the British government and studied in the UK, or from USAID and studied in the USA. More recently, South Africa has become the preferred study destination for students wishing to study engineering.

In 2015, there was a total of 3 942 Swazis studying at South African universities, 40% of whom were studying by correspondence, through the University of South Africa. A total of 59 engineering students graduated – 11 completing degrees, 18 BTechs and 30 national diplomas.

The Eswatini government offers bursaries for engineering students to study outside the country, as do many trading partners. At present several students are studying in Taiwan as part of the programme to strengthen the mining industry. Several students have also studied in Russia through arrangements with the Eswatini government. They are obliged to come back and work in the country to pay off the investment, otherwise they are expected to repay 50% of the cost.

GRADUATE TRAINING

Once the tertiary education phase is complete, it is necessary for graduates to receive structured training in the workplace, under professional supervision and mentorship, to develop to the level of competence required for professional registration, and to be able to take on work independently. Apart from training being offered by a few of the larger consulting practices and utilities, little support is offered in the training of graduates. Furthermore, low numbers are absorbed by organisations that offer training, due to budget constraints.

It was reported than many diplomates were unable to find work, adding to the growing number of unemployed graduates. Having studied mathematics, these graduates do, however, make good mathematics teachers and many are employed in schools.

Those wishing to remain in engineering who are unable to get suitable training opportunities, start operating on their own but without having the practical know-how they do not perform at the level required by clients and struggle to survive.

As there is significant foreign ownership in the large manufacturing corporates, graduate training in that sector tends to take place in regional headquarters, and only those with experience are posted to Eswatini.

To allow Swazis to develop to the level of competence required for professional registration, it is suggested that government-funded graduate programmes be put in place, as described in other countries such as Tanzania and South Africa. Funding should be made available to all parastatals and engineering departments in the ministries to take on graduates, and training should also be a condition of all public-sector tenders. Graduates must be trained towards achieving the outcomes discussed in the next section.

PROFESSIONAL REGISTRATION

As a result of the complaints of poor quality of work and lack of professional supervision covered under the *Workforce* section, a new Act, the Registration of Architects, Engineers, Surveyors and Allied Professionals Act, No. 15 of 2013, was promulgated, to regulate professionals in the construction industry. All professionals working in Eswatini are required to register with the Architects, Engineers, Surveyors and Allied Professionals Registration Council (AESAP) to be able to practise and/or be employed. Registration has been compulsory since March 2017. Progress with registration to March 2018 is shown in Table 4.

Being a relatively new organisation, AESAP still needs to do much work to develop processes and systems. Although it was formed by the government, there is no funding from the government to support the Council, hence there is some urgency to drive registration to develop an income stream from fees.

Table 4: Progress with registration of engineering professionals in September 2018

CATEGORY	Civil	Electrical	Mechanical
Candidate Engineer	10		2
Candidate Engineering Technologist	1	1	1
Candidate Engineering Technician	17		
Candidate Certified Engineering	2		
Professional Engineer	28	7	1
Professional Engineering Technologist	2	3	1
Professional Engineering Technician	5	1	0
TOTAL	**65**	**12**	**5**

AESAP needs to develop outcomes to assess competence; decide on assessment processes; find, select and train assessors; and put Continuing Professional Development (CPD) conditions in place for professionals to retain registration. Furthermore, a system is needed for accreditation of qualifications and to investigate reports of malpractice.

The Royal Academy of Engineering, through the Newton Fund, as part of its support to develop professional bodies in Africa, has made funding available for website development support. AESAP is working with the development team to scope the workflows and content required on the website to automate many of the administrative processes and create awareness of the new requirements.

VOLUNTARY ASSOCIATIONS AND CONTINUING PROFESSIONAL DEVELOPMENT (CPD)

Once they have registered and are practising, it is important for professionals to continue with their development to keep pace with the latest technology, research, alternative solutions and current standards and legislation. CPD is the means by which professionals enhance their knowledge and is a requirement of most registering bodies. CPD is offered by learned societies, training houses and tertiary education institutions, among others.

Limited CPD is on offer in Eswatini. The Swaziland Association of Architects, Engineers and Surveyors (SAAES) is a long-standing association, which was set up to represent the professions related to the construction industry. SAAES has existed for the furtherance of members' careers and the dissemination of knowledge and innovation. The association has several levels of membership, from students and graduates through to registered professionals. SAAES has become largely inactive as many of the earlier drivers have either left the country or passed away. As SAAES largely represented older foreign professionals, the Swaziland Association of Indigenous Construction Consultants (SAICC), also known as *Imvukuzane*, was formed to encourage the development of Swazi consultants and professionals. It has been an informal group to date. To be recognised as a VA by ASEAP, the organisation will need to develop a constitution and set up systems and services.

It has been suggested that SAAES and Imvukuzne should merge to form a strong voluntary association representing the interests of all engineering professionals in Eswatini, able to address the development needs of graduates and professionals now being registered.

To strengthen AESAP, SAAES and SAICC, funding is required, and neighbouring registration bodies and voluntary associations need to lend a hand with advising and supporting these organisations.

WOMEN IN ENGINEERING

The Royal Academy of Engineering, through the Newton Fund, has also made funding available to support the development of a Women in Engineering Chapter in Eswatini. The very successful South African *WomEng* leaders have been appointed to support this development. They will assist with leadership and entrepreneurship training, and with the implementation of programmes pioneered by *WomEng*, including high school STEM awareness, university employability, entrepreneurship and skills training for female engineers.

THE WORKFORCE

It is estimated that there are some 1 600 engineering practitioners in the country. Many of the older practitioners are foreign nationals, while the young group are mainly Swazis.

THE PRIVATE SECTOR

The main employers in the private sector are consulting, contracting, manufacturing, supplier and mining companies. Lower number are employed in small entrepreneurial companies, NGOs, training organisations and other companies where engineering input is required.

Consulting

There were 26 consulting engineering firms registered with Construction Industry Council Eswatini (CIC) in October 2018, the larger ones being part of South African-owned or international companies, in most cases having taken on Swazi partners. The smaller consulting firms are generally Swazi-owned, although over the years some substantial Swazi consulting firms have developed.

The categories of registration include professional engineers, who represent multi-disciplinary practices, and professional mechanical or electrical engineers, as well as professional mechanical or electrical technologists. A practice will not be registered unless one of the directors is a registered professional engineer or technologist. It is estimated that consulting practices employ approximately 200 engineers, technicians and technologists.

Contracting

There were 440 general building (B), civil (C) electrical (E) or mechanical (M) works contractors registered with the CIC in October 2018, along with many specialist contractors registered to supply various types of fittings, finishes and services. There is a grading system, from 1 to 4 or 6, depending on the category, based on the amount of capital, the best annual turnover and the size of the largest project undertaken in the past. Companies categorised at grade one may only handle very small projects, but there is no limit on the size of projects that companies rated at the top grade may handle.

Given that contracting requires significant capital for machinery and equipment, the larger contractors have substantial foreign ownership. The largest of the contractors are Inyatsi Construction Group Holdings and Stefanutti Stocks Swaziland. These companies employ substantial teams of engineering professionals sourced throughout the region.

The smaller contractors employ few, if any, engineers, engineering technologist or technicians. Historically, many construction projects were undertaken in Eswatini without qualified professional supervision, which resulted in poor-quality building and lack of financial control. This situation put clients at risk financially and in terms of quality and the safety of construction practices. The CIC Eswatini was set up through the Construction Industry Council Act, No. 14 of 2013, to address the situation.

As companies in the top grade employ between 5 and 50 engineers and technicians, the next grade, between 1 to 5, and the smaller grades are generally owned and operated by tradesmen, it is estimated that there are some 250 to 300 engineers, technologists and technicians working in construction companies.

The CIC's role is to regulate the construction industry, giving priority to Swazi firms through policy implementation, establishment of ethical standards, practices and procedures, and setting and promoting safety standards. It is also a requirement for all contractors to belong to the Swaziland Contractors Association, a voluntary association set up to represent the interests of contractors.

Manufacturing

There were some 42 construction-related manufacturing companies registered with the CIC in October 2018. However, there are many more companies in agro-processing and smaller companies making small volumes of goods for the local market. Total employment in the sector in 2014 was approximately 60 000, with 15 000 alone in the textiles sector.

Tertiary qualified engineering personnel are used mainly by the large corporates, who tend to post technical staff from regional headquarters to serve one or more contract periods in Eswatini. There are no dedicated private sector manufacturing associations in Eswatini. The Federation of Swaziland Employers and Chamber of Commerce (FSE&CC) represents the interests of members across full spectrum of the private sector.

Based on the number of engineers, technologists and technicians employed in the sugar mills and the food and beverage companies, it is estimated that there are approximately 150 engineering practitioners engaged in manufacturing.

Mining

The only mine and the quarries employ just over 1 000 personnel, but only a few tertiary qualified engineering personnel.

THE PUBLIC SECTOR

Many engineering practitioners are employed in the public sector, particularly in the state-owned entities such as the EEC, EWSC and the EPTC.

Table 5 shows the ministries and departments where the majority of engineering practitioners are to be found. Returns from these departments suggest that there are least 600 employed in government. The estimate is increased to 650 to cover those in local government and ministries employing only one or two engineers. Several ministries reported vacancies and difficulty in attracting engineering staff due to low salaries. Some complained of vacancies of up to 50%.

The development of technicians and technologists in the EEC and EPTC is offered by ESCOT on their behalf, based on specific City and Guilds qualifications which

Table 5: Ministries employing engineering practitioners

MINISTRY/STRUCTURE
Ministry of Agriculture • Eswatini Water and Agriculture Development Enterprise
Ministry of Commerce, Industry and Trade
Ministry of Housing and Urban Development • Human Settlements Authority
Ministry of Health
Ministry of Information, Communications and Technology • Eswatini Posts and Telecommunications Corporation (EPTC) • Department of Communications • Computer Services Department • Eswatini Broadcasting and Information Services
Ministry of Natural Resources and Energy • Eswatini Electricity Company (EEC) • Eswatini Water Services Corporation (EWSC) • Department of Water Affairs • Department of Geological Survey and Mines
Ministry of Public Works and Transport • Department of Public Works • Department of Roads • Eswatini Civil Aviation Authority (ESWACAA) • Eswatini Railways • Royal Eswatini National Airways Corporation

they have selected. Employees move from trainee technicians to senior technical officers depending on the level of the qualification completed and experience gained over the years.

MIGRATION TRENDS

As discussed throughout, there are many foreign-owned companies or partners in Swazi businesses. The Construction Industry Council Act and other Acts and policies seek to encourage the development of Swazi businesses and Swazi nationals. As there are limited engineering education opportunities in Eswatini, many students study outside the country, and few return to join the local workforce. The diaspora can be found worldwide, many having settled in South Africa.

The brain drain is considered to be a big problem as even those who studied locally leave the country once they have gained some experience. Salaries are also said to be an inhibitor as the most experienced engineering professionals in Eswatini earn half to a third of what their South African counterparts earn.

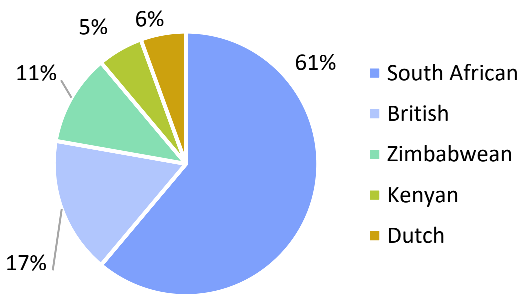


Figure 12: Nationalities of foreign engineering practitioners registered with the AESAP

Analysis of the United Nations Population Division statistics for 2015 shows a net loss of all categories of professionals each year, with 90% of emigrants moving to South Africa. Figure 12 shows the distribution of foreign nationals registered with AESAP.

ENGINEERING NUMBERS AND NEEDS

The success of the manufacturing sector and of tourism, which relies on the main transport networks, would not be possible without a team of experienced engineers. Considering the input received, there is clearly a need for more experienced engineering practitioners. However, to develop such capacity is a long-term exercise covering tertiary education, graduate training and later on technical specialisation, management and leadership. It is estimated that there are some 1 600 practitioners as shown in Table 6.

Table 6: Estimated numbers of engineering practitioners in the engineering workforce

SECTOR	ESTIMATED NUMBER
Academia and research	50
Agriculture	50
Consulting	200
Contracting	280
Government	650
ICT, systems and telecommunications	50
Manufacturers, including sugar mills and suppliers	150
Mining	10
Miscellaneous and NGOs	160
TOTAL	**1 600**

Currently some 270 engineers and technicians graduate in Eswatini per year, and at least 100 graduates outside the country. Figure 13 shows the current workforce, the losses that will occur over the 18-year period to 2035 due to retirement, mobility and mortality, and the growth of engineering capacity assuming a 2% increase in graduation rates per year.

The blue dotted line shows the growth in skills that would be required at the 2017 GDP growth rate of 1.6% and the green dotted line shows the growth based on the 2018–2023 GDP projection of 1%. A 70% employment elasticity factor has been used to extrapolate the employment demand.*[1]

The current numbers exceed the requirements and given the slow growth recently, this situation is unlikely to change for some time. Even considering the projected growth suggested by Agenda 2063, numbers will be excessive. This explains the current problem of unemployed graduates. Consideration needs to be given to limiting the number of students and ensuring that there is sufficient investment for quality education.

Even if the numbers are cut back, graduates will not be absorbed and trained unless the government reprioritises its budgets and makes substantial investments in infrastructure development and

[1]* Employment elasticity is a measure of the percentage change in employment associated with a 1% change in economic growth. If the growth is likely to be in agriculture, the percentage could be lower, as growth in that sector is generally to do with productivity gains and not employment, while if the growth is likely to be in high tech manufacturing, the elasticity factor maybe more than 100%.

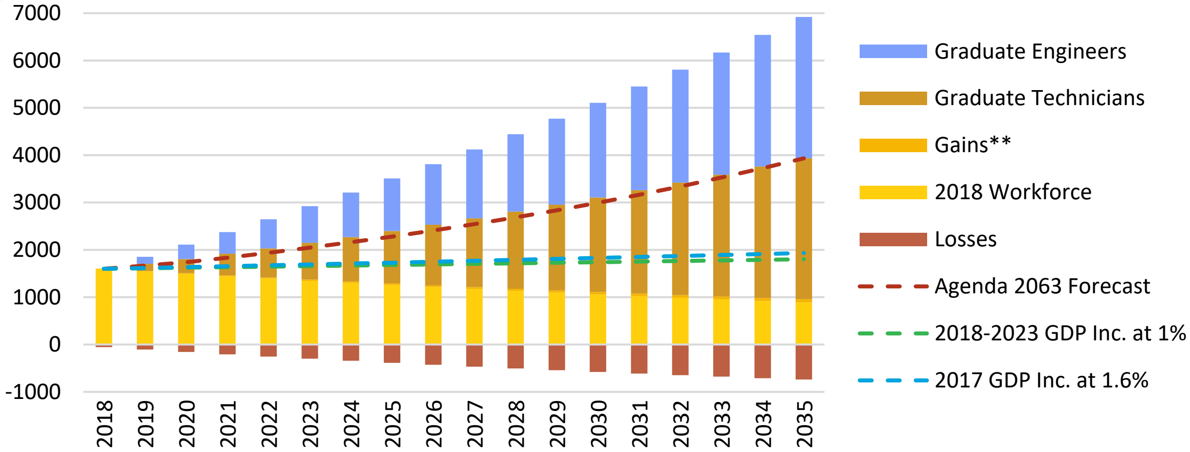


Figure 13: Flow of engineering skills based on a 2% increase in graduation rate per year

***Excludes international engineering practitioners in the country on short-term contracts*

maintenance, and assigns funding to formal graduate training programmes.

The development of many smaller cohorts of engineering practitioners, should be considered to optimise processes and systems and contribute to the growth of the GDP. When reviewing the number required, consideration should be given to the following:

- **Agricultural engineering:** The focus of the Biosystems qualification and the absorption and success of graduates needs to be reviewed. Attention needs to be given to the agricultural engineering requirements of Eswatini, including the development of further irrigation capacity for both commercial and subsistence farmers, levels of automation, post-harvest facilities and management, water resource management and climate change challenges, among others.
- **Chemical engineering:** There are few chemical engineering practitioners in Eswatini. However, given the need to increase energy supplies, food and beverages, pulp and paper processes, etc., bursaries should be made available for chemical engineers to study outside the country, linked to manufacturing initiatives to grow the economy.
- **Civil engineering**: Civil engineering practitioners are the largest group, with many technicians trained locally through ESCOT. Engineers are, however, required to plan and lead development. Bursaries should be made available for young Swazis to complete civil engineering degrees outside the country each year. The number of technicians studying civil engineering needs to be curtailed to achieve lower student-to-lecturer ratios. The content of the qualification also needs to be reviewed, considering industry needs.
- **Electrical, electronic and telecommunications engineering:** There are many electrical engineering practitioners, the largest group being employed by the EEC. Given plans to generate more electricity locally and to take electricity to every household, the current capacity will need to keep growing. Electronics graduates are required in automation and control while ICT capacity is required for the increasing telecommunications and information technology sectors. The number qualifying and the qualifications need to be reviewed to ensure that they match industry needs.
- **Industrial engineering:** There are few industrial engineering practitioners in Eswatini. They could, however, play a significant role in terms of improved production and streamlining systems. Consideration should be given to offering bursaries for industrial engineers, linked to manufacturing initiatives to grow the economy.
- **Mechanical engineering:** Mechanical engineers are required to develop production processes, and technicians to oversee ongoing maintenance and quality control. Mechanical engineering capacity is also needed for water treatment plants, pumping schemes, hydroelectric systems, wind turbines, heating, ventilation and air conditioning (HVAC) among others. Consideration should be given to offering bursaries for studies outside the country from time to time.
- **Mining engineering and metallurgy:** There are only a handful of mining and metallurgy practitioners in Eswatini. An increase is required if new mines are to be developed and older mines revived. Metallurgical engineers will be required to support the reworking of the Ngwenya Mine tailings. Consideration has already been given to sending Swazis overseas to complete degrees in mining and metallurgy. It

will be necessary to ensure that graduates are given sufficient years of structured training on the mines, under the supervision and mentorship of experienced mining engineers and metallurgists, before they will be ready to move to more strategic planning and management positions.

KEY RECOMMENDATIONS

To develop a sound pool of engineering professionals, able to contribute to the well-being of Eswatini, the following should be considered:

Schooling

- **Mathematics and Science**: Strengthen the teaching of mathematics and science to increase the numbers completing secondary education with acceptable results.
- **Career guidance**: Expand career guidance to attract high-calibre entrants into the engineering profession, incorporating programmes to reach female learners, and rural and low-income areas.
- **Bursaries**: Provide bursaries to attract those who excel in mathematics and science to study engineering.
- **Studies outside the country:** Offer bursaries for students to study chemical, civil, industrial, mechanical and mining engineering and metallurgy outside the country as required and ensure that international institutions selected offer qualifications that will be recognised by the AESAP. The numbers should be based on demand from industry and public sector structures.

Tertiary education

- **Accreditation:** Develop a rigorous national accreditation programme in collaboration with AESAP to ensure the quality of engineering education using the guidelines of the Washington and Dublin Accords.
  - Review the content of the electrical engineering and biosystems qualifications at UNESWA and ensure they are industry relevant and work towards meeting the requirements of the Washington Accord.
  - Enhance the curriculum of the civil engineering national diplomas offered by ESCOT to suit the construction sector, and mechanical engineering national diplomas to include production and maintenance management, and work towards meeting the requirements of the Dublin Accord.
- **Top-up support:** Offer top-up training for civil and mechanical engineering graduates of the past in construction and maintenance management.
- **Industry liaison:** Liaise with industry on a regular basis to ensure that curricula, methods, software and equipment are relevant and up to date and that numbers being trained match the demand.
- **Curricula:** Provide funding to research, modernise or develop curricula and material where required.
- **Facilities:** Raise funding to upgrade lecture theatres, libraries and laboratory facilities where required.
- **Resources:** Raise funding for computers, engineering software, access to online reference material, and laboratory and other equipment, and ensure adequate support to offer technology-relevant training.
- **Attract and retain academics:** Improve conditions of service, support and packages to attract, retain and appoint additional academics.
- **Academic development:** Provide funding for lecturer post-graduate development and facilitate opportunities for academics to gain experience in industry.

Graduate training

- **Develop programmes:** Develop national graduate training programmes to ensure graduates achieve the level of competence required by industry and for professional registration.
- **Private sector incentives:** Offer incentives for private sector companies to develop graduates.
- **Public sector support:** Ensure that public sector structures take on and train graduates and that they are absorbed and developed through the ranks.
- **Institutional support:** Institutionalise graduate training in all organisations by setting KPIs for experienced staff to act as supervisors and mentors.
- **Project support:** Make graduate training a requirement of all public sector projects and ensure that the progress of graduates is monitored, and penalties are imposed for non-compliance.

Professional registration

- **Registration:** Fund the development and strengthening of AESAP to develop a rigorous registration process, and systems until it is able to operate as fully fledged registration body.
- **VAs:** Recognise and support the development of voluntary associations in the engineering sector and encourage the merging of SAICC and SAAES.
- **Promote registration:** Publicise the need for registration and the benefits to employer bodies.

Continuing development

- **CPD:** Fund the development of a robust CPD system, monitored by AESAP but rolled out by the various voluntary associations and tertiary institutions, to include courses, workshops, conferences, online learning etc.
- **Validation:** Validate short courses and skills programmes for a specified period only to ensure that training remains up to date and relevant.
- **Post-graduate studies:** Provide post-graduate bursaries to develop specialists.
- **Develop managers and leaders:** Encourage industry to continue investing in graduates after professional registration to grow management and leadership capabilities.

Registration of service providers

- **Regulations**: Expand the consulting and contracting regulations to:
  - Cover increasing the use of local consultants, contractors, labour, plant and materials.
  - Ensure that foreign consultants and contractors partner with local companies.
  - Ensure that there are requirements for consultants and contractors to train graduates, artisans and other construction-related skills.
  - Ensure that international consultants provide all calculations, drawings, operating manuals and other reference material in English.
  - Ensure that local consultants, along with the client, check that design proposals address local needs and customs and that design calculations comply with national codes and standards.
- **Quality**: Implement quality assurance on all projects and ensure penalties are imposed for poor performance.

The public sector

- **Maintenance:** Invest in maintenance to preserve new infrastructure and prevent further deterioration of existing infrastructure.
- **Tariffs and payment:** Review and increase tariffs where appropriate, and enhance domestic revenue collection and demand management to fund development.
- **Technical capacity:** Reprioritise budgets to fill vacancies, build technical capacity, ensure that salaries are competitive and develop succession plans to make the public sector an employer of choice.
- **Technical decision-makers:** Ensure that engineers are employed in senior decision-making posts.

Industry-wide collaboration

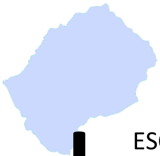
- **Advisory team:** Set up an engineering advisory team, recognised by government, to advise on and endorse infrastructure development proposals, tertiary curricula and graduate training programmes.
- **Collaboration:** Encourage all professional bodies to work together to share knowledge, exchange best practice and ensure coordinated planning of industry support initiatives.

ACKNOWLEDGEMENTS

The detailed picture presented would not have been possible without the support of many associations, government departments and local professionals. Thank you to Ramford Zwane, MD of ED Simelane & Associates, chairman of AESAP, and to Bob Pullen and Johan du Plessis, supporting AESAP, who assisted with initial meetings with a number of government departments, state-owned-entities and major companies. Thank you to Rejoice Maseko, Director of the Department of Research, Science & Technology, and her dedicated team for collecting a substantial amount of outstanding data. Thank you, too, to a number of companies who made information available and for ideas provided by passionate engineers in various consulting firms.

SOURCES OF INFORMATION

Most information and data were gathered when engaging with various Swazi organisations and engineering practitioners. Comprehensive data was received from parastatals, ministries and engineering bodies. Additional information was gathered from SADC reports, master plans and strategies as listed under *Plans and Strategies,* and from many standard international sets of data as listed in Chapter 5, *Research Approach*. Further information was gathered from news articles, annual reports, the Central Bank and the Department of Statistics.



LESOTHO

LESOTHO, officially the Kingdom of Lesotho, is landlocked by South Africa and is criss-crossed by a network of rivers and mountain ranges, including the 3 482 m-high peak of Thabana Ntlenyana.

The Kingdom of Lesotho is made up mostly of highlands where many villages can be reached only on horseback, by foot or light aircraft. The urban population represents only 27% of the total population.

The recommencement of diamond mining in 2002 has contributed significantly to the economy, as did the development of the Lesotho Highlands Water Project, the first phase of which was completed in 1998. The Letšeng diamond mine produces the highest-quality gem diamonds in the world, and in terms of altitude, is also the highest diamond mine in the world.

Apart from water and diamonds, resources are scarce – a consequence of the harsh environment of the highland plateau and limited agricultural space in the lowlands.

Almost 60% of the population live below the international poverty line and unemployment is widespread. Over the decades thousands of workers have been forced by the lack of job opportunities to find work on South African mines.

In 2017, Lesotho had the world's third-highest prevalence rate of HIV/AIDS at an estimated 16% of the population, putting a further strain on the country's economy.

Its capital and largest city is Maseru, which is the commercial centre. The population of 330 760 in 2016 constituted half of Lesotho's urban population. Rural dwellers seeking employment and better services, combined with continuing retrenchments in South Africa, have increased the population of Maseru beyond its carrying capacity, resulting in the growth of slum areas and an escalation in unemployment and poverty.

THE ECONOMY

Lesotho depends on a narrow economic base of mining, tourism, textile manufacturing, agriculture, remittances and regional customs revenue. About three-quarters of the population live in rural areas and engage in animal herding and subsistence farming. Lesotho produces less than 20% of the nation's demand for food. The country also relies on South Africa for much of its economic activity and 90% of the goods it consumes are imported. Households depend heavily on remittances from family members working in South Africa, in mines, on farms, and as domestic workers.

PLANS AND STRATEGIES

To address development, several important plans and policies have been drawn up, including:

- **Lesotho Vision 2020** which, when formulated in 2000, was the long-term strategy aimed at ensuring that Lesotho becomes a prosperous nation with a well-developed human resource base and strong economy by 2020. Many of the plans below have been developed in response to this vision.
- **National Strategic Development Plan (NSDP) (2012/13–2016/17)**, incorporating Vision 2020, which is a framework for transforming the economy and intellectual and skills profiles to achieve the capacity to produce goods and

Table 1: Lesotho metrics

Population	
Total	1 953 000
Urban	27%
Rural	73%
Poverty, HIV, Unemployment	
Below the international poverty line	59.6%
HIV-positive	16.4%
Unemployment	25.3%
Human Development Index	0.497
Electricity	
Production kWh	510m
Consumption kWh	847.3m
Ports and Airports	
Airports	24
- Paved	3
- Unpaved	21
Kilometres of Services	
Roads	5 940
- Paved	1 069
- Unpaved	4 871
Africa Infrastructure Development Index	16.01
Access to Services	
Access to safe drinking water	78%
- Urban	91%
- Rural	73%
Access to improved sanitation	26%
- Urban	32%
- Rural	24%
Access to electricity	17%
- Urban	43%
- Rural	8%
Telephones	28 206
Mobile phones	2 282 917
Internet users	27%

services for the large southern African markets, the African continent and beyond.

- **Lesotho Energy Policy (2015–2025)** which aims to overcome the constraints in energy supply to drive the economy and improve the livelihoods of the people.
- **Water and Sewerage Company Strategic Plan (2015–2020)** aimed at realigning the entity to expand its service and ensure sound governance, financial sustainability and commitment to customers.
- **Industrialisation Master Plan (2007–2010)** aimed at understanding and overcoming constraints and expanding manufacturing capacity to increase employment and address national poverty. The focus areas are strengthening the textiles, garments and leather sectors, and expanding the manufacture of electronic devices for export.
- **National Action Plan for Food Security (2007–2017)** aimed at improving market infrastructure, remedying unsustainable land use practices, supporting smallholder farmers and improving the resilience of the rural poor.

ENGINEERING ACTIVITIES

Figure 1 shows the contribution of engineering-related economic activities, which contribute some 45% to the country's GDP. The largest sectors are manufacturing followed by mining (the latter has increased rapidly since 2002). Considering each in turn will give a picture of the activities, trends, challenges and opportunities for the engineering profession to contribute to Lesotho's growth.

AGRICULTURE

Currently, agriculture is mostly subsistence-based, with only 10 registered commercial farmers in 2015. Topsoil erosion, drought, floods and overgrazing have led to a sharp decline in agriculture. In September 2013, Lesotho signed the Comprehensive Africa Agriculture Development Programme Compact (CAADP), committing to achieve the goal of raising agricultural productivity by 6% and ensuring that 10% of the budget is allocated to agriculture. Government initiatives, such as communal cooperatives, aim to strengthen the industry. Lesotho's arable land covers only 9% of the total land area, a small percentage of which is used for irrigated crops. The main crops of maize, sorghum and wheat occupy 60%, 20% and 10% of agricultural land respectively.

Land tenure remains an obstacle to increasing agricultural productivity because land is not owned outright. Following traditional property allocation practice, all land is held by the King who serves as a trustee for protecting the country's natural resources. As a result, there is no legal market for the sale of rural land, inhibiting investment in development.

Subsistence farming

Two-thirds of the working population rely on the land for food, income and employment; some 80% are smallholders. The latter cultivate small plots of land, with very low agricultural productivity. Grain and cereals are generally produced for home consumption. As a result, agriculture does not generate much income but holds immense potential for contributing to economic growth – generating employment and reducing poverty levels.

A problem for many small farmers is the absence of equipment or technology to utilise land in a productive way. In addition, poor transportation and communication infrastructure in remote regions limits contact between rural farmers and the agricultural extension specialists responsible for sharing strategies. Livestock also provides a significant proportion of rural income, with milk being traded locally and wool and mohair being sold in larger towns and urban areas.

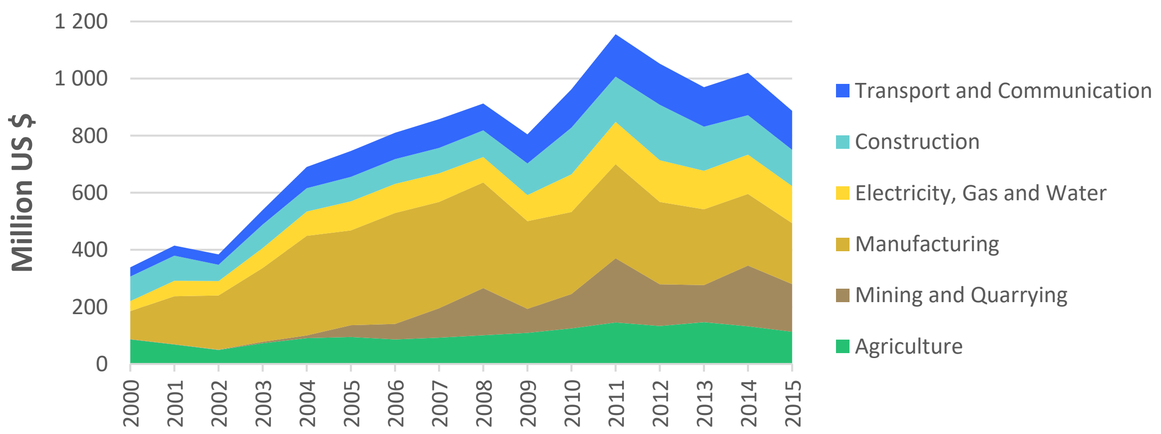


Figure 1: GPD per engineering-related economic activity (44% of the GDP)

The Smallholder Agricultural Development Programme (SADP), which commenced in 2012, aims to support smallholders to explore opportunities and increase productivity. Rolled out in four districts, the SADP's focus is on irrigated vegetable production, wool and mohair, dairy, piggery and poultry hatcheries.

The Ministry of Agriculture and Food Security employs several civil engineering technicians who design and assist with installation of and training on irrigation systems, and mechanical engineering technicians who train farmers on how to operate and maintain farming equipment. Their view is that much of the equipment is not suitable for women to use, and they lament the lack of funds to research and develop appropriate technologies.

Government subsidies for summer cropping in 2012/2013 have resulted in total grain production of 154 000 metric tons compared with an average of 42 000 metric tons in previous years. Such support to farmers has both continued and intensified since 2012 and needs to be further expanded.

Commercial farming

There are only a few commercial farms focused in niche areas such as vegetable, fruit and poultry production. The country's elevation, good soil and abundance of water lends itself to the production of vegetables and fruit trees, for export to South Africa and EU markets. Fruits generally ripen earlier than in other countries in the southern hemisphere, offering an opportunity to supply the regional market early in the season. The NSDP recognises the need to develop the following:

- Water harvesting infrastructure and an increase in irrigation capacity, including building dams or channels from large dams to make water available
- Basic infrastructure to reduce isolation
- Distribution and marketing systems and promoting investment in agri-businesses.

Forestry

According to the Food and Agriculture Organization of the United Nations (FAO), 1.4% of the land is forested, making Lesotho one of the least-forested countries in Africa. Forest resources can be categorised into indigenous trees and shrubs, and government-owned plantations. Indigenous trees provide fuel and construction wood for the rural population, while government-owned plantations, created as part of the Lesotho Woodlot Project, are not a major contributor to national income due to deteriorating roads, losses due to fire and a decline in reforestation activities.

Fisheries

An economic spinoff from the development of the Lesotho Highlands Water Project has been the near-perfect water conditions for trout farming. Commercial trout farming commenced in 2014 and by 2016, 4 000 tons were being exported to South Africa and Japan annually, a figure that is expected to increase considerably by 2018.

MINING AND QUARRYING

The country's major mineral resource is diamonds extracted from five major mines, namely Lets'eng, Liqhobong, Kao, Kolo and Mothae. The diamond sizes and quality are exceptional, with a 910 carat, D colour diamond being discovered in the Letšeng mine in early 2018. By July 2018, 11 diamonds greater than 100 carats had been recovered since the beginning of the year. This will ensure that Letšeng remains the world's highest dollar-per-carat diamond operation for the foreseeable future.

Other mineral deposits include gravel, sand, fire clay, dimension stone and base metals. The country also has small amounts of uranium, coal and iron. Since most building materials, including bitumen, are imported, consideration needs to be given to using macadam road construction techniques to utilise the extensive deposits of stone available.

The mining sector contributes significantly towards tax revenues and export earnings. According to the NSDP, all of Lesotho's mining companies were planning substantial expansions of their operations, leading to further growth. The investments were expected to increase diamond exports from R1.7 billion in 2010/2011 to an estimated R9.0 billion in 2016/2017. Exploration for coal and shale gas is also underway.

MANUFACTURING

Manufacturing concerns in Lesotho comprise food products and beverages, textiles, clothing, footwear and leather, electrical and electronic appliances, furniture, ceramics, handicrafts and jewellery. Textile and garments firms, which are predominantly owned by foreign companies, are the dominant industry. In the recent past there have been investments in other key subsectors, such as electronics and plastic products.

The manufacturing sector is the largest private employer and the largest contributor to exports,

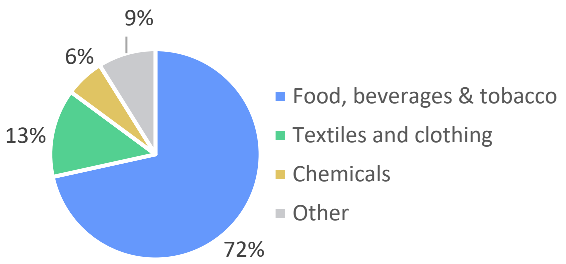


Figure 2: Manufacturing value add per subsector

driven mainly by textiles and garments manufacturing, making it the largest textiles exporter to the US under the African Growth and Opportunity Act (AGOA).

The Lesotho Industrialisation Master Plan of 2007 outlined the need to improve manufacturing infrastructure by ensuring that all industrial sites are fully serviced with electrical power, water and liquid-waste disposal facilities, and are equipped with shell factory units for leasing to entrepreneurs. Construction of the first shells was due to commence in 2018. Benefits are, however, limited because the current Land Act makes it unattractive for private investors to acquire land for long-term operations because of limited ownership and leasing rights.

Food, beverages and tobacco products

Lesotho imports 70% of its annual food consumption, mainly from South Africa. Food processing and the production of bottled water, wines, soft drinks and beer take place on a small scale, mostly in Maseru. Several mills process grain to produce flour, maize meal, samp, animal feed and sugarcane to produce sugar.

One of the largest food processors was the Basotho Fruit and Vegetable Canner (Pty) Ltd which produced canned products such as baked beans, peaches, asparagus, fruit juice and tomatoes, and boasted a strong export client base. Sadly, it has not operated since the end of 2015, at which time the major shareholder withdrew support.

Textiles, clothing and leather

The textile, clothing and footwear manufacturing industry remains Lesotho's largest formal private sector employer – employing around 46 500 workers in 2017.

AGOA has resulted in growth in the industrial garment sector. The garment industry is divided into factories producing garments manufactured from knitted cloth and clothes produced of woven cloth, including denim. There are more than 40 clothing factories. The main job categories are sewing, cutting, joining, counting, laundry, checking, ironing, packing, cleaning, loading/unloading and reception, none of which require technical skills, as shown in Table 2.

Table 2: Clothing worker's level of education by gender

GRADE	M	F
Standard 7/Grade 7	18%	33%
Junior Certificate/Standard 9	8%	22%
C.O.S.C/Matric	5%	16%
Tertiary education	0%	0%

However, in terms of textiles, there are manufacturers that produce fabric and yarn using cotton sourced from elsewhere in Africa. The Formosa Textile Company, for instance, has a spin-yarn dye-weave textile mill which specialises in the production of denim fabric and cotton yarn, and has the capacity to produce 3 million yards of denim fabric and 900 tons of cotton yarn per month. It employs roughly 900 workers, including 15 to 18 engineers and technicians as required.

Following the global economic crisis in 2008, textile producers have struggled to compete with low-cost producers in Asia, which the industrialisation policy seeks to address.

Leather manufacturing is also important, with two companies producing some 7 million pairs of shoes per year.

Timber, pulp, paper and packaging

The majority of wooden products, building materials, paper and packaging materials are imported from South Africa. Small, generally portable sawmills provide local wood, mostly for small artisanal furniture manufacturing businesses.

Plastics, chemicals and other non-metallic mineral products

Although plastic is the waste type most generated by households, plastic waste is largely taken care of by a local factory that collects and uses the waste to produce plastic bags and plastic ware. The waste is cleaned and shredded before being pelletised and mixed with virgin plastic (bought from South Africa) to make products through extrusion and blow-moulding processes.

Chemical manufacturing capacity is very small, with the bulk of the chemicals being imported from other countries, especially South Africa. An emerging area is detergent production. In terms of skills, chemists and laboratory technicians are needed to test all imported and local products to ensure that they comply with international standards.

After years of purchasing cement and construction materials from South Africa, a cement blending and packing facility was constructed in Maseru in 2017. The plant, which has a capacity of more than 200 000 tons a year of bagged cement, will meet the current local demand for cement, while also being capable of producing specialised products for large infrastructure projects such as the Lesotho Highlands Water Scheme. Building materials such as cement bricks and blocks are also produced locally.

Pharmaceuticals

Lesotho produced its own pharmaceuticals during the South African apartheid era to ensure that it had access to drugs should the borders with South Africa be closed. The country was successful at selling its pharmaceutical products, which included TB treatments, antibiotics, creams and beauty products, to the (previous) Southern African 'Bantustans' and many countries in Africa. However, they did not work towards 'Good Manufacturing Practice' (GMP) certification, and once Nelson Mandela had been released and international trade resumed with South Africa, the Lesotho Pharmaceutical Corporation did not survive in the face of competition. Today, small manufacturers make creams and cosmetic products, and local herbal medicines that promise to cure all, using basic equipment rather than large plants requiring engineering skills.

Computer, electronic and optical products, and electrical equipment

The Industrialisation Master Plan included plans to commence the manufacturing of electronic devices and the Lesotho National Development Corporation (LNDC) has widely promoted the assembly of consumer electrical and electronic appliances as an area for development. The LNDC reports that four companies assemble electronic and electrical products, such as television sets and circuit-breakers, for international and regional brands. It is understood that Philips commenced production in Lesotho but has since closed.

Metal industries, machinery and equipment

Construction material, machinery and equipment are generally imported, largely from South Africa. The automotive industry in Lesotho is a recent development which will focus on the manufacture of small components for supply to South Africa's strong automotive industry.

ELECTRICITY, GAS AND WATER

Electricity

The Lesotho Highlands Development Authority (LHDA) is the main generator of electricity through its Muela Hydro Power Station. The power generated from the Katse and Mohale Dams through the Katse Intake Tower provides 72 MW, which represented some 50% of Lesotho's electricity requirements in 2016.

Before the power station was built, Lesotho was 100% dependent on South Africa, from which it still sources power to make up the deficit. Lesotho also purchases power from Mozambique when required. Due to the difficulty with transmitting power through the rugged terrain, only 17% of the population had access to electricity, made up of 43% of the urban population and 8% of the rural population in 2013. A target of 50% has been set for 2020. No comprehensive targets in relation to the SE4All goals for 100% access to electricity have been set.

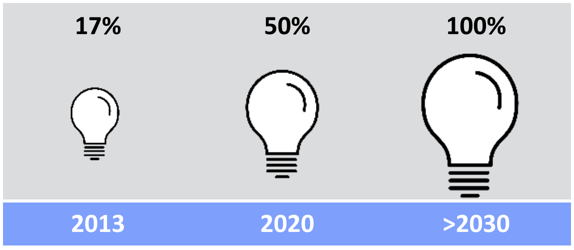


Figure 3: Target dates for access to electricity

The Lesotho Electricity Company (LEC) is a parastatal which is wholly owned by the government, whose mandate is to transmit, distribute and supply electricity. In 2015/2016 it was able to provide 15 000 new connections and expects to continue increasing connections at a similar rate, which bodes well for achieving the 2020 target.

To address the difficulty in providing energy to rural communities, the Renewable Energy-Based Rural Electrification Project pioneered solar panel installations in rural areas from 2007 to 2013, with 5 000 rural households benefiting. The installation and maintenance of the solar panels was done by solar photovoltaic (PV) artisans who were locally trained.

A new hydroelectric plant, capable of generating power of between 1 000 MW and 1 200 MW, is planned at Muela to cover Lesotho's power deficit, estimated at between 170 MW and 200 MW, leaving the bulk for Lesotho to sell to South Africa.

Oil and gas

Lesotho has no known oil or gas reserves and is dependent on South Africa for 95% of its imports. There are five importers and marketing companies involved in the distribution and retailing of petroleum products.

Water and sanitation

Given the many dams and the relatively high rainfall in the highlands, water is readily available, thus 78% of the population had access to safe drinking-water while 26% had access to improved sanitation facilities in 2014.

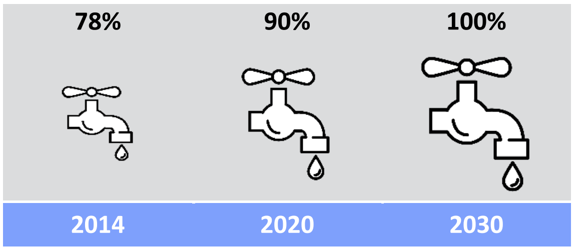


Figure 4: Target dates for access to safe drinking water

The Water and Sewerage Company (WASCO) is mandated to deliver bulk water to urban households and industry, while the Department of Rural Water Supply (DRWS) provides rural water supplies to small settlements. The operation and maintenance of water schemes is the responsibility of local authorities and local committees. The Long-Term Water and Sanitation Strategy developed in 2014 set the 2030 goal as *'All Basotho will have access to appropriate and affordable water and sanitation services according to desired service levels'.*

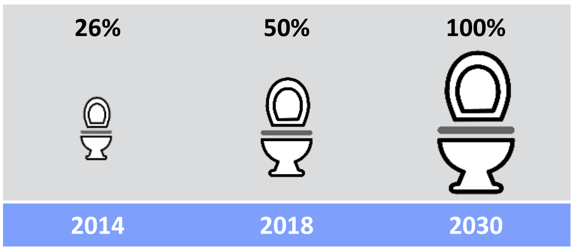


Figure 5: Target dates for access to improved sanitation

WASCO's intention is to add 30 000 water connections by 2020 and 6 000 new sewerage connections, contributing towards the 2030 goal. WASHwatch the international advocacy hub that monitors progress with the delivery of safe water, sanitation and hygiene facilities suggests that at the current rate of progress the sanitation target will not be reached until 2039. Some of the challenges that affect the company's ability to deliver efficiently are non-conformance to regulatory requirements, poor condition of infrastructure and poor project management.

The Lesotho Highlands Water Project (LHWP) is Africa's largest water-transfer scheme, serving both Lesotho and Gauteng province in South Africa. Lesotho receives about R 700 million a year in royalties from South Africa, which represents some 10% of government revenue. The annual budget for operation and maintenance of the project is R81 million.

In 2016, Phase Two of the LHWP was approved, at an estimated cost of US$1.9 billion. This will have a significant impact on the construction industry and will have multiplier effects in ancillary activities such as transportation, trade and business services. The LHWP II is expected to create approximately 3 000 direct project construction jobs.

TRANSPORT AND COMMUNICATION

Given Lesotho's topography, the development of local transport networks is challenging and given its locality, the country relies a great deal on South Africa for its transport, sea ports and, to a large extent, telecommunication services.

Roads

The total road network is 5 940 km, of which 1 069 km was paved in 2013. Prior to the development of the LHWP, paved roads were limited to the main route into Lesotho from South Africa, and roads in and around Maseru. The LWHP has had an important impact on Lesotho's infrastructure, as hundreds of kilometres of engineered paved roads were built to improve access to the different construction sites, and, together with engineered unpaved 'feeder' roads around the dams, these roads continue to provide much improved access for many villages in the mountainous interior. The rollout of the LHWP II is likely to increase the need for roads to be either built or upgraded.

The Ministry of Public Works and Transport is tasked with developing a national road network that links the entire country, in addition to developing and maintaining inter-urban roads, bridges and footbridges. An important development will be the upgrading of the Mpiti-Sehlabathebe Road to a tarred surface to improve ease of access to the Sehlabathebe National Park and communities along the way.

Rail

Since 1905 Lesotho has had only 1.6 km of rail from the border bridge over the Mohokare River to the station at Maseru. The line is connected to South

African railways and goods are transported to Bloemfontein before being routed to a main centre for consumption or to one of the South African ports for export – usually Durban.

Airports

The government has realised the need to upgrade Moshoeshoe International Airport to meet the existing and forecasted demand for passengers and freight. Upgrades will include expanding the runway to handle larger aircraft, construction of a VIP terminal building and installing navigation aids in compliance with international aviation standards. The upgrade will also benefit South African farmers, specifically in the Free State, who export products to Europe and the Middle East through OR Tambo or Cape Town international airports.

Communications

There are two major network operators in Lesotho, namely Econet Telecom Lesotho and Vodacom Lesotho. In early 2017, although there were only 28 206 fixed-line telephone lines (a reduction from 50 000 in 2014), representing just 1% of the population, and there were some 2.28 million mobile connections, surpassing the population with a penetration rate of 103%. The number of internet users totalled 647 570, representing 27% of the population.

Although landlocked, Lesotho has benefited from connectivity to the landing of several submarine fibreoptic cables on the African east and west coasts of the continent, which saw bandwidth quadruple in 2012. However, Lesotho's international connectivity (other than connectivity through satellite) depends entirely on South Africa. A number of fibre optic links, including Maputsoe, Mabote (over powerline) and Maseru Bridge on the Lesotho side connect Lesotho with South Africa.

Vodacom has selected Lesotho as a test bed for the 5G revolution. The setup network allows a delivery speed of up to 700 megabits per second, which could in future provide safe technology for driverless cars, robots and machines in factories. Furthermore, 5G is seen as a more viable alternative to fibre cabling which is far more expensive to implement by comparison.

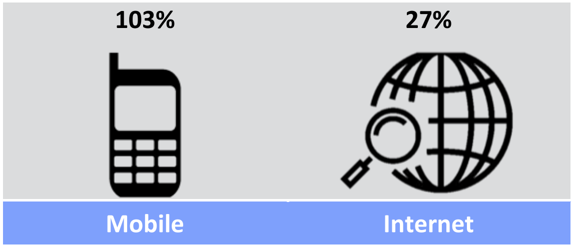


Figure 6: Percentage of population connected to services

In 2013, the government, in partnership with the African Development Bank (AfDB), embarked on a Telecommunications and ICT project to enhance good governance through the deployment of modern and secure e-government broadband infrastructure. The initiative was also aimed at strengthening existing government data centres and portals, and improving access to e-services for state building, such as automated administrative services and revenue management. The total estimated cost of the project was US$12.8 billion, starting in 2013 and due for completion in 2020. The following are some of the outcomes to be achieved:

- Increased level of accessible online services and citizen participation
- Improved ICT skills for the government workforce
- A 100 km core fibre network in the metropolitan area, a fibre link to Mohale's Hoek and telecom towers in rural areas
- Expansion of the existing two data centres from two servers to 10 servers
- Training of 500 ICT professionals.

Figure 7: Katse Dam in Lesotho
(Courtesy: LHDA)

Table 3: Major projects identified, or being planned or under construction

PROJECT		VALUE US$	START YEAR	END YEAR
Water & Energy	Lesotho Highlands Water Project II – Water transfer to South Africa and generation of 1 000 MW hydropower at Muela	$1.92bn	2020	2025
	Lesotho Lowlands Water Supply Scheme Unit (LLWSSU) Phase II – 765 km pipeline, 81 large reservoirs and 57 small reservoirs			2020
Airports	Moshoeshoe International Airport upgrade	$91.67m	2016	2019
Roads	Mpiti-Sehlabathebe Road (upgrade 91km gravel to tar)	$89m	2018	2021
Other	Mothae Mining Project	$60m	2019	2021
	Butha-Buthe Factory Shells	$55m	2018	2021
	Roma Valley Development	$41.67m	2017	2019

CONSTRUCTION

Construction is important in any country due to its ability to create jobs and develop skills. With the development of LHWP II, the construction sector is set to take off once again with not only the LHWP II itself, but also access roads, accommodation facilities, power supplies, telecommunication facilities and residential development. The major projects planned in the coming years are listed in Table 3.

Housing

Given rapid urbanisation, there is significant pressure in terms of housing development and providing the associated services, as outlined in the previous sections. However, Lesotho does not have a current housing policy, the most recent being produced in the late 1980s which was never implemented, apart from the formation of the Lesotho Housing and Land Development Corporation (LHLDC).

According to data given to Habitat for Humanity's Audit of Housing Policy in Lesotho, 70% of housing supply is informal. Informal development occurs very rapidly but, as in formal development infrastructure is not being developed in a sustainable way.

The Lesotho Housing Profile (2015) estimated that a total of 99 000 dwellings will have to be constructed by 2025 to meet the demand for housing in Lesotho.

LOCAL GOVERNMENT

Local government is predominantly two-tier, dictated by the Local Government Act, No. 6 of 1997, with district councils as the upper tier and community councils as the lower tier. The capital Maseru has its own unique single-tier authority, the City Council. The first Council was appointed in 2005. Recently, the number of community councils has been reduced from 128 to 64, to align with the national parliamentary constituencies, following which 11 urban councils have been established.

Water and electricity are supplied by the utilities as outlined previously. Urban councils are expected to look after the well-being of their population and must control natural resources and protect the environment, attend to health, burial grounds, parks and markets. They must plan and allocate sites, develop and manage minor roads, streets, street and traffic lights, and provide emergency services. They are also responsible for the removal and management of waste.

Municipalities would prefer to purchase energy and water in bulk and to plan, implement, operate and maintain the distribution networks themselves. They believe that as they provide many other services, and are closer to local communities, they are better situated to interpret their requirements and provide for their needs. Municipalities are, however, struggling with high vacancies, as do other public sector structures.

EDUCATION, TRAINING AND PROFESSIONAL DEVELOPMENT

Education and training is a vital part of developing engineering capacity. All elements, from teaching appropriate subjects at schools to continuing professional development (CPD), need to be in place to educate and train engineering personnel and to ensure that they remain abreast of the latest technology, challenges and emerging solutions. Lesotho spends a higher proportion of its GDP on

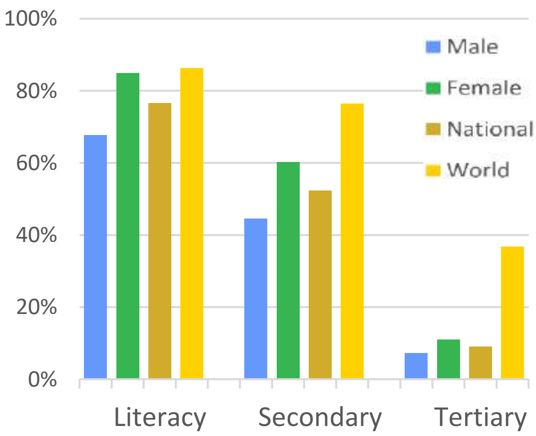


Figure 8: Literacy and enrolment statistics
(UNESCO from 2014 to 2016)

education than any country in the world. However, the quality and level of education attained is low, due to inadequate resources and poor retention rates at primary and secondary levels.

PRIMARY AND SECONDARY EDUCATION

Primary education is fully funded, spans seven years and is compulsory. On passing Grade 7, a Primary School Leaving Certificate is issued, which is a prerequisite for entering secondary school. Secondary education is broken into Junior Secondary School for the next three years followed by Higher Secondary School for two years, after which O-levels are written. The secondary level enrolment rate in 2014 was 52%.

The major obstacles to increased access and transition to secondary education are the limited number of classrooms and the inability of families to pay school fees. The lack of qualified teachers, particularly in rural areas, textbooks and facilities in general result in poor throughput rates.

TERTIARY EDUCATION

There are 13 institutions recognised by the Council for Higher Education, of which eight are public and the balance are private. The four largest institutions are the National University of Lesotho (NUL), Lerotholi Polytechnic (LP), Lesotho College of Education and the Limkokwing University of Creative Technology. Lerotholi has offered trade and technician qualifications for many years and has recently substantially increased the numbers in civil engineering and water-related studies. NUL has concentrated on electronics and computer systems engineering qualifications since 1999, and more recently commenced technology programmes addressing chemical engineering and biotechnology, as shown in Table 4. Although low numbers are taken on each year per qualification, the throughput is high, as students are generally sourced from the science faculty after passing first year BSc science subjects. NUL has realised the need to offer engineering qualifications in many other disciplines to produce engineers who can understand and address local needs. They plan to develop a much-expanded engineering faculty offering chemical, civil, electrical and mechanical engineering in the next five to 10 years. Lerotholi is pursuing transformation into a University of Technology in order to provide professional manpower development in the engineering and technology fields. This will afford it the opportunity to offer degree programmes.

Given that the engineering workforce is composed of some 1 150 engineering practitioners, the total number graduating is too high for industry to absorb each year. The electronics graduates from NUL have largely been absorbed by the growing telecommunications sector over the years, but as service provision has started to reach saturation, the opportunities for recent graduates are limited.

Students from Lerotholi complain of not being able to get placements for internships, and even those who are successful struggle to find employment after graduation. There is said to be limited liaison between the college and industry, but industry also advises that although they would be happy to train students and graduates, opportunities for such training are limited due to the lack of public sector work at present.

Employers also commented on the calibre of graduates, saying that they were not prepared to use their initiative but needed to be shown over and again what processes to follow. There is a need to transform the curricula from teaching engineering processes to engineering problem-solving.

The graduation statistics per institution are shown in Figure 9 and Figure 10, and are split by discipline, category and gender in Figure 11.

Table 4: Engineering graduations in Lesotho in 2014

INSTITUTION	Chemical	Computer Systems	Biotechnology	Civil	Electrical & Electronics	Mechanical	Water & Environmental
National University of Lesotho (BEng)		11			9		
National University of Lesotho (BSc)	12		5				
Lerotholi Polytechnic (ND)		37		101	63	36	93
TOTAL							
Engineer (20)		11			9		
Technologist (17)	12		5				
Technician (330)		37		101	63	36	93

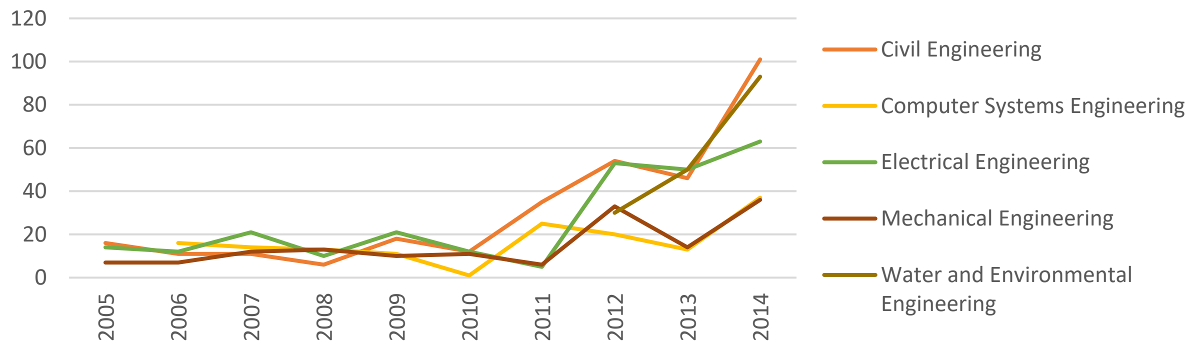


Figure 9: Engineering graduates from Lerotholi by discipline

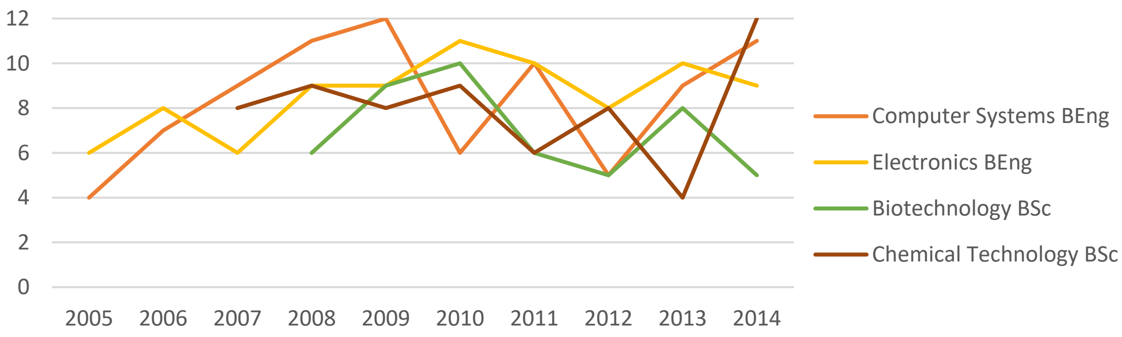


Figure 10: Engineering graduates from NUL by discipline and qualification

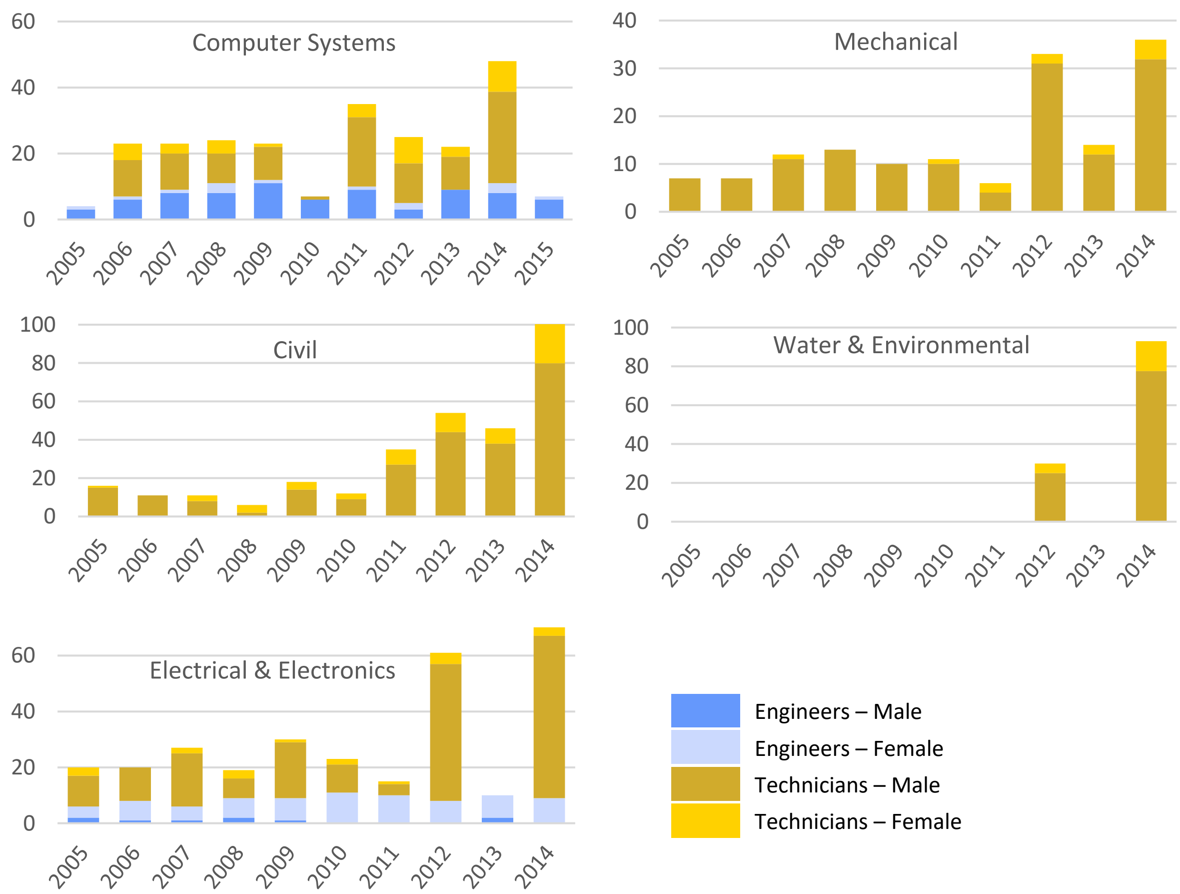


Figure 11: Engineering graduates by discipline, category and gender

LESOTHO

Lesotho has invested substantially in tertiary education, but this has been supply-driven without considering the demand. The result of the exclusive focus on formal education and training has been a skills mismatch. The number of teachers qualifying per year, for instance, greatly exceeds the demand, and unemployed graduates and school-leavers have become the biggest portion of the unemployed labour force. The Ministry of Development Planning has been tasked to prepare a National Manpower Development Plan. From 2019 they will publish quotas per qualification that they will fund, to focus their investment in qualifications and occupations that are in high demand.

Students and graduates complain of the lack of lecturers, laboratories, equipment and software, all of which are essential for a quality education experience. It appears that enrolment numbers should be reduced, and funding should be focused on quality rather than quantity. In terms of the Manpower Plan, it will also be necessary to look at the applied occupations, such as trades, to determine whether more energy and resources should be focused at this level rather than at diploma level.

Accreditation

The Lesotho Council for Higher Education (CHE) is the regulatory body that accredits higher education qualifications. Professionals from industry, the Lesotho Association of Engineers (LAE) and educational specialists from South Africa are asked to review qualifications and comment on their suitability. International norms such as the Washington and Dublin Accords are, however, not considered by the CHE in this process. However, NUL is working towards recognition under the Washington Accord with the help of the University of Pretoria and the Engineering Council of South Africa (ECSA).

Of concern is the fact that the diploma in Electrical & Electronic Engineering offered by Lerotholi was only granted probationary accreditation status from 2014 to 2017, and yet several graduated during that period.

Study mobility

In 2015, there were a total of 3 383 Basuto studying at South African universities, 744 of whom were studying by correspondence through the University of South Africa and 972 at the University of the Free State. A total of 81 engineering students graduated – 13 completing degrees, 39 BTechs and 29 national diplomas.

The Ministry of Development Planning offers bursaries for qualifications that are not available in Lesotho, such as mining engineering. The most common study destinations are China and South Africa. Students are expected to return to Lesotho to work back the investment, but often they do not return. A more structured approach to managing the return of graduates and their development locally is required.

GRADUATE TRAINING

Once the tertiary education phase is complete, it is necessary for graduates to receive structured training in the workplace, under professional supervision and mentorship, to develop to the level of competence required for professional registration, and to be able to take on work independently. The LHDA has implemented graduate internship programmes, which cater for mining, civil and geotechnical engineering, and the Roads Directorate also offers graduate training. Apart from these initiatives and structured training being offered by a few of the larger consulting practices, little support is offered in the training of graduates.

Where conditions are included in public sector tenders to take on students and graduates for their industrial attachments, or to develop as young professionals, the programmes are not monitored, and incumbents find themselves doing menial tasks or sometimes not being involved in the projects at all. Structured training must become part of all public sector projects and must be monitored by the Ministry of Public Works and Transport, which is the custodian of the engineering profession.

PROFESSIONAL REGISTRATION

Lesotho does not have an Engineering Act. By 2018, a major campaign had been mounted to finalise and have a bill adopted for the registration of engineers, consulting engineers and construction companies operating in Lesotho. A draft Local Construction Industry Development Policy (LCIDP) has been submitted to the Ministry of Public Works and Transport for consideration. The intention is to set up a Lesotho Construction Industry Council (LCIC) to register contractors and a Council for Built Environment Professions (CBEP) to register professionals. These may be two bodies or may be a combined body.

VOLUNTARY ASSOCIATIONS AND CONTINUING PROFESSIONAL DEVELOPMENT (CPD)

The Lesotho Association of Engineers (LAE) was first registered in 1982 and after a period of reduced activity from 1993 to 2014, the LAE was re-launched on 28 August 2014. The current constitution recognises the need to foster and promote the art and science of engineering and its application in Lesotho. The LAE considers that its role is to advise government, public bodies and other organisations or individuals on matters concerning engineering and to cooperate with educational institutions and public educational authorities for the furtherance of education and training in engineering science and practice.

The LAE are working in close liaison with the South African Institution of Civil Engineering (SAICE) towards establishing a formalised candidacy programme for built environment graduates, with specific focus on engineering disciplines. They have also signed an agreement with SAICE to access some of the SAICE CPD activities.

WOMEN IN ENGINEERING

With the small membership of the LAE, a women's chapter has not been established. Career guidance efforts do, however, also focus on women and the percentage of female engineering graduates has increased substantially since 2010.

THE WORKFORCE

Due to the limited traction gained by the LAE to date, comprehensive data on engineering practitioners in Lesotho is not available, but from engaging with each sector it is estimated that there are some 1 150 people with engineering qualifications employed in the country.

This agrees well with the 2011/2012 Continuous Multi-purpose Survey which suggested that there were 1 441 architects, engineers and related technicians in the country with degrees, diplomas or certificates awarded post high school. As this study is not considering architects, quantity surveyors and those with certificates, the number of engineering practitioners will be a few hundred less than 1 441, which supports the estimate of about 1 150.

It is hoped that once the Bill is in place, a comprehensive database of all built environment professionals will be developed, which will give a more comprehensive picture and support more accurate skills planning.

THE PRIVATE SECTOR

The main employers in the private sector are consulting, contracting, manufacturing, supplier and mining companies. Lower numbers are employed in small entrepreneurial companies, NGOs, training organisations and other companies where engineering input is required.

Consulting

There are some 50 local consulting engineering firms, employing between 100 and 150 engineers, engineering technologists and technicians. Most of these staff are Basotho, many of whom were trained in South Africa, the UK or India. Several firms have recorded substantial vacancy rates – some complaining of the difficulty of retaining local staff, while others advise that current work levels are such that they have chosen not to fill posts as staff have left their employ.

Where large projects are advertised, large international, often South African, consulting practices are appointed, as tenders call for 20 years of experience and more. International companies are required to work with local companies to develop skills on each of the projects. However, this is not monitored, and little skills transfer takes place. The LHDA has set criteria for the LHWP Phase II that require service providers to '*develop skills and technology transfer programmes … which will be implemented for the duration of the contract as well as provide opportunities for young professionals who will be mentored and trained by key staff. The objective being that they achieve significant career progression on LHWP Phase II for post-construction operations and maintenance with the LHWP as well as further afield.*' Strict control of these conditions will be necessary.

Contracting

In the absence of a Construction Industry Council, each government department has taken to developing its own categories of contractors and criteria for selecting contractors for different sizes and types of contract. Notably, the Department of Rural Water Supply, the Ministry of Public Works, Youth and Gender and the Lesotho Electricity Corporation follow this approach. Considering their registers suggests that there are at least 1 400 contactors in Lesotho, ranging from category A, able to carry out work over the value of US$125 000, to category D, who are restricted to work up to the value of US$12 500. There are about 30 companies in category A, about 100 in category B, some 400 in category C and the balance in category D.

Given that contracting requires significant capital for machinery and equipment, the larger contactors have substantial foreign ownership. Sadly, even for small projects, supply chain criteria are set to ensure that 'preferred' service providers are awarded projects, in return for financial considerations. In the absence of legislation controlling the construction sector, little can be done to protect local contractors, or to enforce quality of work from preferred contractors. Political interference also presents a major problem, as politicians agree to projects that are not high priority, or that are agreed to at inflated prices, affecting the fiscus.

Manufacturing

The manufacturing, industrial supplies and agro-processing sector includes some 20 000 companies, the majority of which fall into the MSME categories and employ some 70 000 people. About 4 600 companies in total are classified as small and medium (employing between 3 and 9, and 10 and 49 staff respectively), but only 9% are in manufacturing, suggesting that there are only about 400 small and medium manufacturing companies and fewer than 200 employing 50 or more.

The largest sector by far is the textile sector, which employs some 46 000 people. Few MSMEs employ engineers and technicians, but use simple production methods. The number of technical staff in large companies varies from one artisan or technician in, for example, basic food-processing operations or equipment suppliers, to five to 20 engineers and technicians in steelworks, mills and the textiles factory. It is estimated that there are between 100 and 150 engineers and technicians working in the sector.

The Basotho Enterprises Development Corporation (BEDCO), a parastatal and subsidiary of the Lesotho National Development Corporation (LNDC), was set up to build sustainable enterprises contributing to national economic growth. The Lesotho Chamber of Commerce and Industry (LCCI) represents the interests of all businesses, including manufacturers.

Mining

The mining and quarrying sector has grown rapidly since the 1990s. As of 2017, there were five diamond mines and two sandstone quarries in full production. Lesotho has an estimated 405 kimberlite bodies in the form of pipes, dykes or offshoots.

The mining industry employs about 3 000 people, a figure that is expected to double as new mines commence production. The Ministry of Mining anticipates that by 2020 the industry will employ more than 10 000 people.

THE PUBLIC SECTOR

Many engineering practitioners are required in the public sector, including in municipalities, to plan new services, issue project tenders and oversee the delivery of, and operate and maintain infrastructure. Table 5 shows the departments that are the main employers of engineering skills. A census of the skills in these departments has been carried out and, allowing for an additional 20 to 30 who may be employed in structures not requiring large numbers, it is estimated that the public sector employs some 350 engineering practitioners.

Of concern is the number of vacancies which were highlighted. The Roads Directorate advised of 50% vacancies, the LHDA 12%, the LEC 10% in technical posts, and the municipalities have few technical staff.

Table 5: Ministries employing engineering practitioners

MINISTRY/STRUCTURE
Ministry of Agriculture and Food Security
Ministry of Communications, Science & Technology • Lesotho Communications Authority (LCA)
Ministry of Defence and National Security
Ministry of Development Planning
Ministry of Energy • Lesotho Highlands Development Authority (LHDA) • Lesotho Electricity Company (LEC)
Ministry of Forestry, Range and Soil Conservation
Ministry of Health
Ministry of Local Government Chieftainship Affairs, including Maseru Municipality and other smaller municipalities
Ministry of Mining
Ministry of Public Works and Transport • Department of Civil Aviation (DCA) • Public Works Directorate • Roads Directorate
Ministry of Small Business Development, Co-Operatives and Marketing
Ministry of Trade and Industry • Basotho Enterprises Development Corporation (BEDCO) • Lesotho National Development Corporation (LNDC)
Ministry of Water Affairs including: • Commissioner of Water (CoW) • Lesotho Electricity and Water Authority (LEWA) • Department of Rural Water Supply (DRWS) • Department of Water Affairs (DWA) • Lesotho Highlands Water Commission • Lesotho Lowlands Water Supply Scheme (LLWSS) • Lesotho Meteorological Services (LMS) • Metolong Authority • Water and Sewerage Company (WASCO) • Water and Sewerage Authority (WASA)

The challenge throughout appears to be the level of remuneration and critical projects not being prioritised and receiving budget.

Despite the investment in developing engineering skills, there is little understanding of the value of appointing and retaining such skills. A scarce skills allowance should be considered to attract and retain high-calibre engineering skills in both technical posts and engineering management roles. There is no career path and succession planning in the public sector. Often as technical staff retire, there is no plan to replace them or ensure that they have groomed in-house staff. As a result, much institutional knowledge is lost, often to the detriment of future service delivery. It has also been reported that vacant technical posts are filled by inappropriately qualified staff, and in the case of senior posts, inadequately experienced staff. Given the number of Basotho qualified engineering practitioners, this should not be the case.

The Department of Labour and the Ministry of Development Planning, when preparing the National Manpower Development Plan, need to collaborate with engineering ministries and the LAE to develop meaningful career paths and competency profiles to ensure that appropriate staff are appointed. It must also include graduate posts in the structures to allow for graduates to be taken on, rotated and trained towards professional competence.

Supply chain management also appears to be a problem, with engineering judgement and decisions on the appropriate products or service providers being overruled by supply chain practitioners, or by legislation. The lowest price should not be taken as the de facto price, as often products are unsuitable, or service providers are unable to deliver for the price quoted or are in the habit of later substantially inflating the cost by means of additional claims. Engineering professionals should be an integral part of the supply chain decision-making process.

MIGRATION TRENDS

Analysis of the United Nations Population Division statistics for 2015 shows a loss of professionals from Lesotho with no gains. The most popular destination was South Africa, representing 95% of the loss, with the remaining 5% moving mainly to other SADC countries such as Mozambique, Botswana and Tanzania. These figures refer only to those who officially emigrated. There is, however, ongoing movement of engineering professionals as local projects are awarded to international companies.

ENGINEERING NUMBERS AND NEEDS

Combining all the data, it would seem that there are approximately 1 150 engineering practitioners in Lesotho, as shown in Table 6.

Table 6: Estimated numbers of engineering practitioners in the engineering workforce

SECTOR	ESTIMATED NUMBER
Academia and research	50
Agriculture	20
Consulting	150
Contracting	160
Government	350
ICT, systems and telecommunications	80
Manufacturers and suppliers	150
Mining	80
Miscellaneous and NGOs	110
TOTAL	**1 150**

Considering all the developments planned, there will be a demand for more qualified and well-experienced engineering practitioners.

In 2015, 367 graduated in Lesotho and a further 81 in South Africa. The total coupled with those who studied in other countries suggests that some 500 are graduating a year. Given that this number is almost half of the regular engineering workforce, graduates have little prospect of finding employment, as confirmed when meeting with a large group of engineering students and graduates in Maseru in early 2018.

It would seem that the number of technicians being trained at present should be reduced to ensure quality education. The large number of graduations only commenced from about 2011. Curtailing classes to achieve an average of 20 graduates per discipline will produce a more realistic scenario.

Figure 12 shows the current workforce, the losses that will occur over the 18-year period to 2035 due to retirement, mobility and mortality, and the growth in engineering capacity if engineering graduations increase at 2% per year over the period. The projection includes an additional 45 graduates coming into the system from 2031 from NUL when it has introduced the new qualifications and assumes that the technician graduations will reduce from 330 to 135 (including those returning from South Africa) by 2021. If not, there will continue to be large numbers unable to find employment.

The blue dotted line shows the growth in skills that would be required at the 2017 GDP growth rate of - 1.6%, and the green dotted line shows the growth

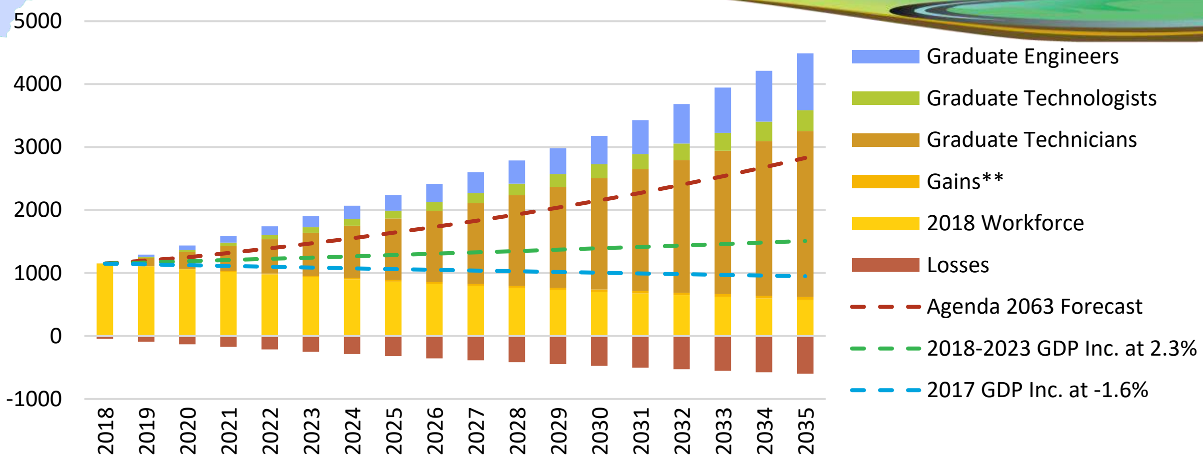


Figure 12: Flow of engineering skills based on a 2% increase in graduation rate per year, but reverting to 100 technician graduates

***Excludes international engineering practitioners in the country on short-term contracts*

based on the 2018–2023 GDP projection of 2.3%. A 70% employment elasticity factor has been used to extrapolate the employment demand.[*1]

Despite including the reduced number of technicians, this scenario will still require substantial graduate support. The development of LHWP II should be used as an opportunity for training those graduating in future years and as an opportunity to train the many currently unemployed graduates.

When reviewing the number required, consideration should be given to the following:

- **Agricultural engineering:** No agricultural engineering qualifications are offered, which is a problem considering the need to increase irrigation capacity both for commercial farmers and to ensure that subsistence farming is sustainable. Consideration should be given to making bursaries available for Basotho to study agricultural or irrigation engineering in neighbouring countries.
- **Chemical engineering:** Chemical technology has been introduced by NUL over the past 10 years. This will play an important role in the food and beverage sectors and in increasing agro-processing. Graduate training in these sectors should be considered.
- **Civil engineering:** With the significant expansion of the LHWP and the need to increase water distribution and improved sanitation, and to develop the roads, it is appropriate for a local civil engineering degree to be offered in time. In view of the need for a steady stream of civil engineers, consideration should be given to making bursaries available for a few Basotho to study civil engineering in neighbouring countries each year. The number of civil, water and environmental technicians has, however, increased to almost 200 per year, which is more than can be absorbed. This number needs to be reviewed urgently.
- **Electrical engineering:** Given the plans to construct major hydroelectric schemes, take electricity to every household and develop a niche market in manufacturing electronic goods supports the need for electrical engineering skills.
- **Mechanical engineering:** There are major roles for mechanical engineering practitioners to play in manufacturing, power generation and mining. Taking into consideration the desire to industrialise, it is appropriate for a local mechanical engineering degree to be offered in time. This should include elements of production and industrial engineering, considering the role that mechanical engineers will play in the manufacturing process.
- **Mining engineering and metallurgy:** With the growth of the mining industry, mining engineers and metallurgists are key to productivity and quality output. Consideration should be given to making bursaries available for Basotho to study mining engineering in neighbouring countries.

There have been calls for specialisations, including bridge engineering, hydropower engineering,

[*1] Employment elasticity is a measure of the percentage change in employment associated with a 1% change in economic growth. If the growth is likely to be in agriculture, the percentage could be lower, as growth in that sector generally has do with productivity gains and not employment, while if the growth is likely to be in high-tech manufacturing, the elasticity factor maybe more than 100%. These considerations will need to be factored into Human Resource Demand Planning.

geotechnical engineering and mining. Although the numbers would not justify providing local post-graduate courses, bursaries should be made available for studying these disciplines outside the country.

KEY RECOMMENDATIONS

To develop a sound pool of engineering professionals, able to contribute to the well-being of Lesotho, the following should be considered:

Schooling

- **Primary and secondary education:** Address the weaknesses in primary and secondary education, and increase the number completing secondary education with acceptable results.
- **Career guidance:** Expand career guidance to attract high-calibre entrants into the engineering profession, incorporating programmes to reach female learners, and rural and low-income areas.
- **Bursaries:** Provide bursaries to attract those who excel in mathematics and science to study engineering.
- **Studies outside the country:** Offer bursaries for students to study civil, industrial, mechanical and mining engineering and metallurgy outside the country as required and ensure that international institutions selected offer qualifications that will be recognised by the registering body when it is in place. The numbers should be based on demand from industry and public sector structures.

Tertiary education

- **Accreditation:** Develop a rigorous accreditation programme in collaboration with the LAE and new registering body to ensure the quality of engineering education using the guidelines of the Washington, Sydney and Dublin Accords.
  - Encourage institutions to develop adequate complex engineering problem-solving content and graduate attributes to satisfy the requirements of the Accords.
- **NUL:** Increase the number of engineering qualifications offered by NUL, but limit class sizes to match the demand and ensure quality education. Work with the international community to plan the new NUL facilities and qualifications to meet Washington Accord standards.
- **Lerotholi:** Review the numbers being trained and limit class sizes to match the demand and ensure quality education.
- **Industry liaison:** Liaise with industry on a regular basis to ensure that curricula, methods, software and equipment are relevant and up to date.
- **Curricula:** Provide funding to research, modernise or develop curricula and material where required.
- **Facilities:** Raise funding to upgrade lecture theatres, libraries and laboratory facilities where required.
- **Resources:** Raise funding for computers, engineering software, access to online reference material, and laboratory equipment, and ensure adequate support to offer technology-relevant training.
- **Attract and retain academics:** Improve conditions of service, support and packages to attract, retain and appoint additional academics.
- **Academic development:** Provide funding for lecturer post-graduate development and facilitate opportunities for academics to gain experience in industry.
- **Research:** Develop research and innovation capacity.

Graduate training

- **Develop programmes:** Develop national graduate training programmes to ensure graduates achieve the level of competence required by industry and for professional registration.
- **Private sector incentives:** Offer tax rebates or incentives for private sector companies to develop graduates.
- **Public sector support:** Ensure that public sector structures take on and train graduates and that they are absorbed and developed through the ranks.
- **Institutional support:** Institutionalise graduate training in all organisations by setting KPIs for experienced staff to act as supervisors and mentors.
- **Project support:** Make graduate training a requirement of all public sector projects and ensure that the progress of graduates is monitored, and penalties are imposed for non-compliance.
- **LHWP II:** Ensure that training opportunities on the LHWP II are maximised and monitored.

Registration of engineering professionals

- **Registration:** Finalise and adopt the Built Environment Professionals Bill, and fund the LAE or a parallel structure to develop a rigorous registration process and registering body. Include all the criteria recommended for registering bodies outlined in Chapter 9.

Continuing development

- **CPD:** Fund the development of a robust CPD system to include courses, workshops, conferences, online learning etc.
- **Validation:** Validate short courses and skills programmes for a specified period only to ensure that training remains up to date and relevant.
- **Post-graduate studies:** Provide post-graduate bursaries to develop specialists.
- **Develop managers and leaders:** Encourage industry to continue investing in graduates after professional registration to grow management and leadership capabilities.

Registration of service providers

- **Construction Policy:** Finalise and fast-track the adoption of the Local Construction Industry Development Policy and develop regulations to:
  - Cover the increasing the use of local consultants, contractors, labour, plant and materials.
  - Ensure that foreign consultants and contractors partner with local companies.
  - Ensure that there are requirements for consultants and contractors to train graduates, artisans and other construction-related skills.
  - Ensure that international consultants provide all calculations, drawings, operating manuals and other reference material in English.
  - Ensure that local consultants, along with the client, check that design proposals address local needs and customs and that design calculations comply with national codes and standards.
  - Limit companies to a certain size or category of work based on their technical skills, past experience and the availability of plant and capital.
  - Ensure that local contractors are developed as part of large projects.
- **Quality:** Implement quality assurance on all projects and ensure penalties are enforced for poor performance.

The public sector

- **Economic infrastructure:** Invest in the development of economic infrastructure such as electricity, roads, rail and airports, and address the supply of water services.
- **Maintenance:** Invest in maintenance to preserve new infrastructure and prevent further deterioration of existing infrastructure.
- **Tariffs and payment:** Review and increase tariffs where appropriate, and enhance domestic revenue collection and demand management to fund development.
- **Technical capacity:** Reprioritise budgets to fill vacancies, build technical capacity, ensure that salaries are competitive and develop succession plans to make the public sector an employer of choice.
- **Engineering decisions:** Review HR, budgeting and supply chain processes and the level of authority given to senior professionals to allow them to make appropriate engineering decisions.
- **Technical decision-makers:** Ensure that engineering professionals are employed in senior decision-making posts.

Planning and collaboration

- **Manpower Development Plan:** The LAE to work with the Ministry of Development Planning and the Department of Labour to develop a robust National Manpower Development Plan and ensure collaboration with tertiary education, and the public and private sectors to determine the demand for, and content of, the qualifications required.
- **National data:** Develop a central database of all occupations for purposes of manpower planning, possibly through the Lesotho Revenue Authority.

ACKNOWLEDGEMENTS

The Numbers and Needs research project was embraced enthusiastically by many in Lesotho, who went out of their way to collect data and give input. Thank you to everyone who contributed, with special thanks to:

Mathealira Lerotholi	Water Commission
Molebatsi Ntja	President, LAE
Ben Rafoneke	Past President, LAE
Seriti Phate	Deputy President, LAE
Leabua Makhate	Secretary, LAE
Lekhooe Makhate	Ministry of Small Businesses Development, Cooperatives and Marketing

Teboho Mokhoane	Ministry of Public Works and Transport
Mamotumi Malapane	Lesotho Consolidated Civil Contractors
Doctor Lukhele	Lesotho Highlands Development Authority
Isaac Morienyane	Isaac and Lesoli (Pty) Ltd
Boitemelo Dillane	Maseru Municipality
Selebalo Moeketsi	Ministry of Agriculture and Food Security
Monica Moeko	Transmission and Distribution Manager at LEC
Daemane Seribetso	Roads Directorate
Dr Leboli Thamae	National University of Lesotho
Motselisi Mokhethi	National University of Lesotho

SOURCES OF INFORMATION

Most information and data were gathered when engaging with various Lesotho departments, the LAE and engineering practitioners. Comprehensive data was received from parastatals and ministries, and much insight was gained at a large workshop hosted in Maseru in March 2018. Additional information was gathered from SADC reports, master plans and strategies as listed under *Plans and Strategies* and from many standard international sets of data as listed in Chapter 5, *Research Approach*. Further information was gathered from news articles and from Labour Force Surveys. Comprehensive documents focusing on specific issues in Lesotho as listed below were additional sources of information.

Enviro-Tech SA. 2014. *Baseline assessment of waste management in Maseru City*. Boksburg, South Africa: Enviro-Tech SA.

Hlabana, M. 2007*. The role of Lesotho's textile industry in promoting local economic development. The Thetsane Industrial Area*. MA Dissertation, University of the Free State, South Africa.

LNDC (Lesotho National Development Corporation). 2007. *Project profiles*. Maseru.

LNDC. 2016. *Africa's inspired apparel sourcing hotspot. Lesotho's textiles, apparel & footwear manufacturing industry.* Maseru.

Makoa, R. 2014. *Lesotho national policies, best practices and challenges in building productive capacities* (Lesotho Ministry of Planning). Report to the Workshop on National Focal Points of Least Developed Countries (LDCs) on 27 July 2014, Cotonou, Benin.

Ministry of Tourism, Environment and Culture. 2010. *National Profile of Chemicals Management Infrastructure*. Maseru.

Mokhethi, M.C. and Vögel, A.J. 2015. Export constraints facing Lesotho-based manufacturing enterprises. *Acta Commercii*, 15(1): 1–8.

Mots'oene, K.A. 2014. Housing Implications on Sustainable Development in Maseru – Lesotho. *Journal of Sustainable Development in Africa,* 16(4): 84–101.

SBP (Small Business Project). 2008. *The state of small enterprise in Lesotho*. Report to the Ministry of Trade and Industry, Cooperatives and Marketing. Maseru.

Thamae, T.M. 2008*. Developing and characterizing new materials based on natural fibres and waste plastic.* Kingston, Ontario, Canada: Queen's University

UNDP (United Nations Development Program). 2015. FinScope MSME (Micro, Small and Medium Enterprises) survey. Lesotho. New York: UNDP.

Wikle, T.A. 2015. Subsistence farming and economic hardship in Lesotho, Africa's mountain kingdom. *FOCUS on Geograph*y, 58(2): 79–90.

MADAGASCAR

MADAGASCAR is the fourth largest island in the world, situated in the Indian Ocean, off the coast of East Africa.

Madagascar is the world's principal supplier of vanilla, cloves and ylang-ylang, and now provides half of the world's supply of sapphires, which were discovered near Ilakaka in the late 1990s. A further discovery in 2016 is set to increase production at the expense of biodiversity in the forest regions.

Since the development of the Ambatovy Mine, the production of nickel, cobalt and ammonium sulphate has increased to the level where nickel represented 18.4% of exports in 2016.

According to the United Nations, despite these unique commodities, Madagascar belongs to the group of least developed countries, with some 77% of the population living below the international poverty line.

The capital city is Antananarivo, which is the country's most populous city and home to some three million people living in the metropolitan area and surrounds. The next ten towns are small by comparison, with populations ranging from just over 200 000 down to 50 000. Urban slums are a major challenge in Madagascar, as they house some 75% of the urban population. The balance of 100 towns and villages have fewer than 50 000 inhabitants. Almost 80% of the population is rural, relying on agriculture for their existence.

THE ECONOMY

Madagascar's financial sector remains weak, and the contribution of the financial, trade and services sector to the GDP at just over 30% is the second-lowest in SADC.

Agriculture, including fishing and forestry, is the mainstay of the economy, accounting for more than a quarter of the GDP. Madagascar produces around 80% of the world's vanilla supply which, given current international demand, has driven prices to record highs. As a result, coffee and spices now account for more than a quarter of export earnings. With the increase in mining activities, metals and gems accounted for almost 24% of the export earnings in 2016 and after regaining AGOA access, clothing, knitwear and accessories represented a further 21% of export earnings.

However, with the second-lowest GDP per capita in SADC, and a population of over 24 million, Madagascar relies on aid funding and the support of many NGOs to address health and education challenges, and improve agricultural productivity and access to engineering services.

Over an almost 50-year period, all heads of state (excluding the previous and current President, elected at the end of 2018) have either gained or lost power as a result of an unconstitutional event. Corruption, self-interest and associated political interference in decision-making related to projects and infrastructure have limited investment in the country and undermined the ability of utilities, engineering ministries and structures to roll out projects or operate and maintain existing infrastructure. An inadequate tax-collection system further limits funding for development.

Table 1: Madagascar metrics

Population	
Total	24 320 000
Urban	24.3%
Rural	75.7%
Poverty, HIV, Unemployment	
Below the international poverty line	77.6%
HIV-positive	0.1%
Unemployment	3.6%
Human Development Index	0.51
Electricity	
Production kWh	1.71bn
Consumption kWh	1.59bn
Airports and Ports	
Airports	83
- Paved	26
- Unpaved	57
Ports	4
Kilometres of Services	
Roads	37 476
- Paved	6 103
- Unpaved	31 373
Rail	836
Waterways	600
Africa Infrastructure Development Index	10.73
Access to Services	
Access to safe drinking water	52%
- Urban	82%
- Rural	35%
Access to improved sanitation	12%
- Urban	18%
- Rural	9%
Access to electricity	15%
- Urban	37%
- Rural	4%
Telephones	148 585
Mobile phones	7 998 253
Internet users	5%

PLANS AND STRATEGIES

Several important plans and development policies have been prepared to improve the economy and drive infrastructure development, the most important of which are:

- **Fisandratana 2030** (meaning emergence and rebirth in Malagasy) which aims to double the wealth per capita by 2030 by extending the National Development Plan 2015–2019.
- **Vision 2015** known as Madagascar Naurellement which aims for the country to be industrialised by 2020, tapping into its vast natural resources to create products of high value from the agro, pharmaceutical and mining sectors. Key focus areas include the development of infrastructure, education and health services and tourism.
- **Madagascar Action Plan (MAP) (2007–2012)** updated to the **Best Action Plan (2010–2015)** which provides a roadmap to achieve Vision 2015 and is aimed at mobilising the nation and international partners.
- **National Development Plan (PND) (2015–2019)** whose goal is to ensure that Madagascar becomes a modern and prosperous nation considering five strategic pillars of governance: preservation of macroeconomic stability and support for development; inclusive growth; adequate human capital; and the development of natural capital; and resilience to disaster risks.
- **Economic Development Paper (DDE)** which is a strategy aimed at overcoming poor economic performance and deteriorating social conditions by increasing the revenue base and developing policies to address inhibitors such as land tenure and high inflation rates, among others.
- **National Water, Sanitation and Hygiene Policy (2013–2018)** which describes actions to be taken to achieve the water sector's goals and to reconsider the roles of key players.
- **New Energy Policy (*Nouvelle Politique de l'Energie* (NPE)) (2015–2030)** which lays out a strategy to reach 70% of the population with electricity by 2030 through a range of technologies and Public-Private Partnership (PPP) approaches.
- **Plan for Employment and Training (PANEF) (2015–2019)** which aims to create productive employment, improve productivity and set up a well-functioning labour and training market.

ENGINEERING ACTIVITIES

Figure 1 shows the contribution of engineering-related economic activities to the country's GDP. The largest sector is agriculture, followed by transport and communications, and then manufacturing. Considering each in turn will give a picture of the activities, trends, challenges and opportunities for the engineering profession to contribute to Madagascar's growth.

AGRICULTURE

Agriculture and forestry are the mainstays of the economy, contributing some 25% to the GDP, 70% to the export earnings, and employ about 78% of the economically active population. Although the number relying on the land is high, only 5% of Madagascar is farmed. As a result, the farms are small by world standards, the average size being 0.86 ha.

There are almost 2.5 million farms, mostly family-owned, only 5 000 of which are larger than 5 ha. Just over 2 million are less than 1 ha. Families grow subsistence crops for their own consumption and supplement their income, where possible, by growing cash crops such as vanilla, coffee and cocoa for export, and fruit and vegetables for urban markets. Sadly, most families cannot afford transport and sell to intermediaries able to reach them with off-road vehicles, who pay very low prices.

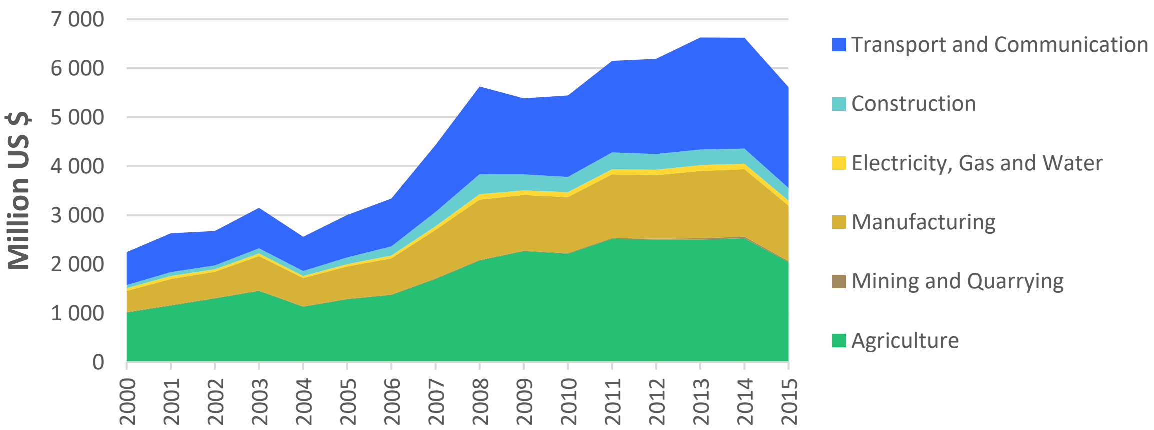


Figure 1: GDP per engineering related economic activity (69% of the GDP)

Furthermore, the condition of many roads is such that crops spoil on the journey to markets – transporting of eggs is particularly problematic.

Large-scale plantations dominate the production of sisal, sugarcane, tobacco, bananas and cotton.

Subsistence farming

Rice is the staple food, grown on about one-half of the agricultural land. The most intensive cultivation is undertaken in the central highlands where steep slopes are terraced to form rice paddies which are irrigated by narrow canals. To improve production, a toolkit, which included information about seed, crop diversification, fertilisers, no-tillage systems and water management, was supplied to farmers with which to experiment. Combining local knowledge and best practice has boosted production.

The area under production could be considerably increased as there are 35 million ha of arable land, with only 1.2 million ha of rice fields under production, but a change of approach and know-how will be required to farm bigger areas. Agronomist engineers are expected to design and develop innovative solutions, systems and processes, but the ratio of engineers to producers is estimated to be 1 to 10 000 and their role is not widely understood.

Irrigation systems, consisting of dams, canals and associated pipes, pumps and valves, were constructed in the 1960s by the Agricultural Department, but fell into disrepair due to lack of maintenance. In the late 1980s, the Department employed consultants to assess all systems and recommend remedial measures. Contractors were employed to rehabilitate the infrastructure, before handing it over to community Water User Associations (WUA), who were expected to take over the duty of managing and maintaining these systems. The model has not been successful, and many irrigation systems once again need attention. A programme to ensure that 40% of farmers benefit from improved irrigation and agricultural inputs by 2022 was being put in place in 2017.

Cash crops and commercial farming

Cash crops that can be grown on small tracts of land, such as vanilla, cloves, fruit, cocoa and coffee, are grown by families to supplement their income. Crops are sold through cooperatives which advise on production, storage, transport and markets. Granaries and other storage facilities, including cold storage, are important for this process.

Sisal, sugarcane, tobacco, bananas and cotton are grown on large-scale plantations, with sugar being grown in the north-west and bananas on the east coast. Irrigation and road transport are important for these crops.

Forestry

Large tracts of land covered in natural forests are under threat and must be protected. More than four-fifths of domestic fuel needs are supplied by wood and charcoal, thus despite major reforestation efforts, the country's total forested area continues to decline. Some 30 large companies, employing 2 000 workers, are involved in forestry. Sawn wood makes up 80% of the wood-based products exported.

Fisheries

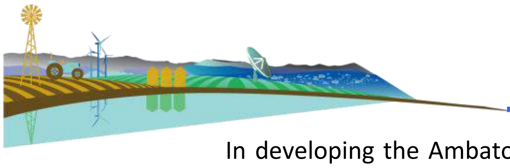
Due to Madagascar's long coastline, fishing is an important part of the economy, for local consumption and for export. Artisanal fishermen trawl along the coast using trawl nets and *valakira* traps, and industrial fishing businesses trawl from 5 km to 30 km offshore using larger boats with refrigeration or freezing facilities. The country exports both inland water and coastal water fish.

MINING AND QUARRYING

Madagascar has many reserves, which include ilmenite, graphite, limestone, gold, platinum group metals, silver, iron, copper, zinc, nickel, cobalt, chromite, coal and uranium. Madagascar is also rich in precious and semi-precious stones, including ruby, sapphire, emerald, aquamarine, etc.

Although Madagascar has a long history of small-scale mining of gold and precious stones, the sector entered a new era with the launch of two large-scale mining projects in the 2000s. The Ambatovy Mine, developed to exploit nickel and cobalt reserves, was the largest private investment ever witnessed on the island, an investment of US$7.2 billion by 2013. The second large project was the development of the QMM Mine in Tolagnaro (formerly Fort Dauphin), developed to exploit one of the world's largest reserves of ilmenite (titanium ore). Investment in this development totalled US$930 million by 2008.

Nickel, which is best known as a component of stainless steel, has recently become used more widely in various materials and products, including batteries, mobile phones and environmentally friendly vehicles. The Ambatovy Mine will produce 60 000 tons of refined nickel, 5 600 tons of refined cobalt, and 210 000 tons of ammonium sulphate fertiliser annually for at least 29 years. This will place nickel as Madagascar's top export, providing a significant stimulus to the economy.



In developing the Ambatovy Mine, it was necessary to build everything from power plants and roads to piers and railway lines, offices and accommodation. The infrastructure comprises a mine and an ore-preparation plant; a pipeline of approximately 220 km, to transport the mined ore in the form of slurry to the processing plant; a processing plant, including a refinery, that produces finished nickel and cobalt metal; and port operations at the Port of Toamasina. It was also necessary to spend millions of dollars to protect forests and endangered animals in a country with a unique ecology.

When developing the ilmenite mine, investment in infrastructure was also required. A new port at d'Ehola, as well as new roads and a variety of mining facilities and housing for mine workers, have been developed. These are the first major investments in the region's infrastructure for many decades. Ilmenite and zircon are to be extracted from the heavy mineral sands over an area of about 6 000 ha along the coast for the next 40 years. A mineral-separation plant will produce 750 000 tons a year when in full production.

Chromium ores represented the second-largest export in the mining sector in 2009. They are produced by a public mining company called Kraomita in east-central Madagascar.

Plans are in place to develop a 136 million ton coal mine in south-western Madagascar, a 60 MW coal-fired power plant and over 200 km of transmission line to address the needs of one of the poorest regions of the country. Production is expected to commence in 2020.

Madagascar has been a top sapphire producer since their discovery in the late 1990s. A further discovery in 2016 is set to increase production at the expense of biodiversity in the forest regions.

Rio Tinto Alcan is interested in mining an estimated 100 million tons of bauxite located near Manantenina, which is approximately 100 km north-east of Tolagnaro.

Madagascar's mining challenges include low investment, poor infrastructure and the smuggling of gemstones, as many deposits are inside national parks and hence off-limits to development.

MANUFACTURING

Manufacturing was stimulated by the formation of the Export Processing Zone (EPZ) in 1996, which offers tax exemptions for export-focused industries.

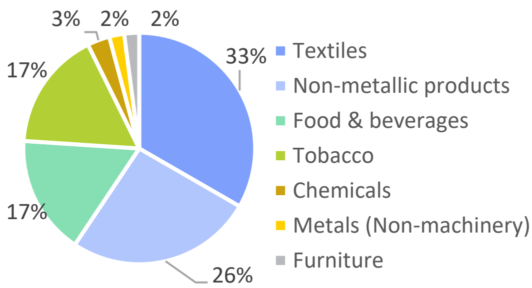


Figure 2: Manufacturing value add per subsector.
(Economic Development Board of Madagascar, 2014*)*

The project has grown to include 150 companies and has generated 80 000 jobs, producing 37.4% of Madagascar's foreign trade revenue. Its main products are clothing (48%), handicrafts (13%) and agro-processing (9%). Textiles are another important export, supported by Madagascar's cotton industry and low wage rates, and accounts for 15% of manufacturing production. Other products include plastics, pharmaceuticals, leather goods, footwear and tobacco. Special Economic Zones (SEZ) are now also being set up to encourage investment in certain localities, not only for export, but also for local consumption.

Manufacturing companies cite logistical problems as major impediments, including customs, inland and sea transport, delays at ports, electricity costs and reliability, poor internet and telecommunications, and high rents. The road between Antananarivo and the port town of Tamatave, a distance of 300 km, is in bad condition. It can take up to one week for containers to travel between a factory and the port due to slow travel speeds. In addition, the capital is plagued by traffic jams. Cargo trucks going in and out of the capital are limited by law to travelling only between the hours of 20:00 and 6:00. Road capacity is another challenge. If production were to increase, the roads might not be able to support a corresponding increase in traffic.

Food, beverages and tobacco products

Breweries are never missing in any country. These require a range of engineering skills for production. In Madagascar, Brasseries Star is the fifth-largest company and produces beers, soft drinks, including international carbonated drinks under licence, fruit juices and bottled water. There are several other breweries and beverage manufacturers.

A number of small sugar mills have recently been developed to increase the processed sugar output. The most developed forms of processing fruit, vegetables, meat and fish in Madagascar are the canning of cooked vegetables, jams and fruit juice making, with tinned green beans and peppers being shipped to Europe and fruit purée to the Indian Ocean Islands. Several rice mills process rice, largely for local consumption. Fish processing is important, with processing plants involved in the freezing, drying, smoking and vacuum packing of meat and fish products for export. Fish waste is processed into meal for animal feed and aquaculture.

SACIMEM SA, a subsidiary of Imperial Tobacco, manufactures 16 million cigarettes a day at Antsirabe, linked with fibre optic for remote control of production and operations.

Textiles and clothing

Textile production is a key manufacturing activity, but there is a need to expand local cotton production, as 75% of the raw material and intermediate inputs are imported. Production of cotton is, however, limited by the ginning capacity locally. The privatisation of the Madagascar Cotton Company (HASYMA, which owns five of the country's large-scale ginning facilities), contributed to the expansion of the cotton industry in the early 2000s. This was achieved by modernising and expanding cotton ginning capacity and by providing technical advice and incentives to local cotton producers and selected domestic private investors. HASYMA promotes the production of cotton seed, purchases and gins seed cotton, and markets cotton fibre, seeds and by-products on the local and international markets.

There were two spinning firms in Madagascar, COTONA and SOMACOU, three knitting and two weaving companies and 91 clothing companies in 2005, but these numbers dipped after Madagascar lost its AGOA status, although the market is recovering since its reinstatement in 2014. Technical capacity is required for the spinning to yarn, and yarn to fabric process. The fabric to clothing stage is, however, labour intensive, and in 2016 was said to offer employment to some 100 000 people.

Timber, pulp, paper and packaging

Sawn timber is used in the building industry, with several manufacturers producing boards, laminates, flooring, veneers, door and window frames, decking and other products, such as poles, pallets and matches. Construction products form a major part of the timber and lumber exports, although production has declined over the years due to deforestation and several plants have closed.

Wood is the most important raw material in industrial paper production, first being processed into wood chips and subsequently into pulp. Paper and a range of cartons, packets, labels and other packaging materials are manufactured. Paper is, however, also imported, the main suppliers being South Africa, followed by China and then by the EU.

Plastics, chemicals and other non-metallic mineral products

Madagascar has about 10 companies processing plastic products, such as tubes, pipes, plates, buckets and bags. The raw materials are imported mainly from South Africa, China, Mauritius, Thailand, France, Korea and India.

Although not large, the chemical subsector produces domestic products such as hygiene and cleaning material, as well as paints, fertilisers and pesticides. There are no large domestic producers of cosmetic products in Madagascar, but the country is a major source of the essential oils used as a raw material in cosmetic production.

Madagascar's three cement plants have a combined capacity of 820 000 tons. Holcim, which has two plants, was ranked as the seventeenth-largest manufacturing company in 2012. Maloci of China owns the other plant. Products supplied include aggregates (crushed stone, gravel and sand), ready-mix concrete and asphalt.

Pharmaceuticals

There is little or no local manufacturing of medicines, except traditional mixtures that do not required sophisticated manufacturing facilities. *Centella asiatica* (pennywort), known for its wound-healing and memory-stimulating properties, is widely grown, and is picked, dried, sorted by hand and milled in the Madagascar Green Products (MGP) factory for export. Local mosquito repellents are also produced.

Prescription medication is imported but faces challenges from black-market products and the associated poor quality.

Metal industries, machinery and equipment

Madagascar has a single publicly owned car company, Karenjy, but it produces very few vehicles as there is no mass production or assembly line because cars are entirely hand-made. Metal products for the construction industry are also manufactured, including sheeting, sections, decking and other structural steel elements, although most construction products are imported.

ELECTRICITY, GAS AND WATER

JIRAMA (Jiro sy Rano Malagasy – Malagasy Electricity and Water) is a state-owned entity tasked with providing electricity and water to urban areas. It has six regional offices which are established in each of the six provinces. The Agency for the Development of Rural Electrification (ADER) and the Ministry of Health, Hygiene and Water provide electricity and water respectively to rural areas.

Electricity

Although Madagascar has sufficient natural resources to generate electricity for the whole population, in 2013 only 15% of the population had access to electricity, made up of 37% of the urban population and a low 4% of the rural population.

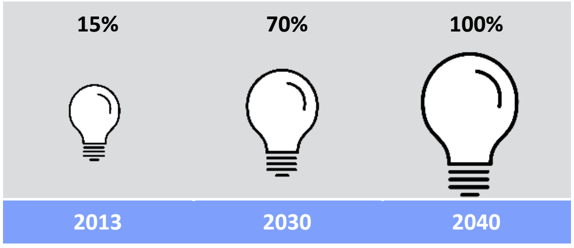


Figure 3: Target dates for access to electricity

The existing networks have been largely unmaintained for years, resulting in high losses and frequent power outages (reportedly 6.7 outages a month, averaging 2.5 hours a week). Furthermore, JIRAMA is under operational and financial stress, limiting the prospects for improved services without external support.

As of 2016, 650 MW was generated, some 70% generated by JIRAMA and the balance through 10 Independent Power Producer (IPP) agreements. Just over 70% of the electricity is generated by six hydroelectric plants and the balance by close on 100 diesel power plants. There is a limited national grid between Antananarivo and the city of Antsirabé, and the rest of the electrified cities and villages rely on isolated small and mini-grids.

In March 2016, the World Bank agreed to make US$65 million available, US$48.62 million of which will be spent on rehabilitation and/or reinforcement of transmission and distribution networks in Antananarivo, and on the upgrading of existing distribution systems in selected districts in order to increase the reliability of the networks. The project will also include technical support and capacity building.

The NPE, published in 2015, aims to ensure access to modern energy services to 70% of the population by 2030 through the expansion of grid, mini-grid and off-grid solutions. The NPE aims to raise the contribution of solar to 5% of the national energy mix by 2030 (from a negligible proportion today). This will come from plants connected to the grid, home systems, solar lights and solar mini-grids.

Specific incentive programmes, such as the Scaling Solar and Scaling Renewable Energy Programme (SREP), will lead to an increase in solar energy well beyond the estimate of 5%. The NPE also encourages the development of PPP schemes and grants concessions to implement these targets. The rural electrification component will be implemented by ADER and National Fund for Electricity (FNE) reforms strengthening both institutions are expected. The implementation of the NPE will be coordinated by a dedicated unit in the Ministry of Energy and Hydrocarbons (MEH).

Oil and gas

According to independent studies, 16.6 billion barrels of oil are in place and recoverable in Bemolanga, with possible additional reserves of 9.9 billion barrels. Madagascar Oil has been producing heavy oil since 2013 from its field in the north-west, and in April 2014 it became the first oil company in the country to receive a 25-year exploitation licence. The company expects to produce an average of 100 000 barrels per day once up to full production, with its principal customer during the test period being JIRAMA.

About a dozen other international oil companies are exploring in Madagascar both on-shore and off-shore, and a number of them plan to commence exploratory drilling in 2018. There are four distributors of petroleum products.

In 2012, high-quality dry gas was discovered in the south-west region. A deposit of around 20 billion cubic metres was also discovered in the south. Once in production, it is expected that the gas produced will provide sufficient energy for all of Madagascar.

Water and sanitation

Madagascar gets a total of 449 billion cubic metres of rainwater per year, more than enough to satisfy the public needs. However, water resources are unevenly distributed and due to a lack of bulk infrastructure, only a few per cent of the annual precipitation is harnessed. As a result, in 2015 only 51.5% of the population had access to safe drinking water, made up of 81.6% of the urban population, and 35.3% of the rural population.

Since the 1980s, many NGOs have mounted projects to develop wells or sink boreholes, to increase water supply in rural areas. The biggest projects have been in the Fianarantsoa Province, which is second-most highly populated, but poorest province.

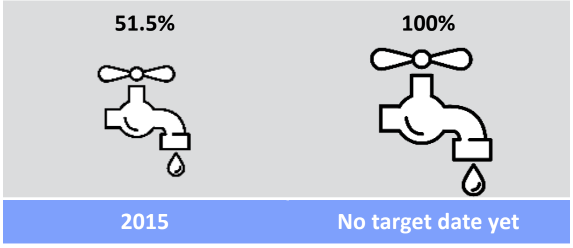


Figure 4: Target dates for access to safe drinking water

Water quality from wells and boreholes is at times a problem due to salinity near the coast and trace elements in higher areas. Furthermore, the sustainability of these facilities is a challenge due to lack of capacity at community level and the non-availability of spare parts. The WASH (Water, Sanitation and Hygiene for All) Committee coordinates the work of all NGOs and donors in Madagascar.

Urban water is provided by JIRAMA, but due to the lack of finance and capacity, the networks have not kept pace with growth. The large number of slum dwellers in cities have limited access to safe drinking water and due to poor hygiene, water quality has become a problem. Although Antananarivo has set up clean water pumps, they remain inadequate and are not distributed according to population density, with limited access in the poorest and most populous parts of the city. Where the supply of water has been privatised, the supply has improved, but residents are not happy with what they consider to be the high costs of the service.

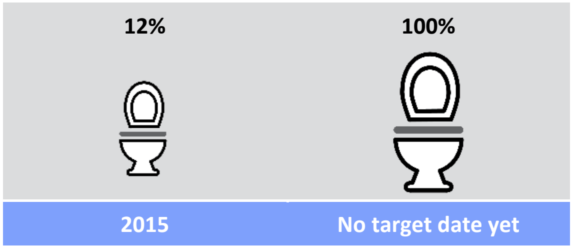


Figure 5: Target dates for access to improved sanitation

The country is challenged with improving sanitation, as in 2015 only 12% of the population had access to improved sanitation, made up of 18% of the urban population and 8.7% of the rural population.

Open defecation is still practised by half the population, and untreated faeces enter water supplies, making water a major transporter of disease. During his tenure, Mayor Ravalomanana constructed public latrines in densely populated and highly frequented areas.

In 1990 targets were set to achieve 100% access to safe drinking water and 70% access to improved sanitation by 2020. As 2020 approaches, Madagascar is nowhere near achieving these targets. Many aid organisations working in Madagascar are playing an active role in the design, construction and management of water and sanitation services. Education to overcome the taboo on digging pits and using latrines, thus possibly disturbing the ancestors, is necessary in some cases.

TRANSPORT AND COMMUNICATION

There is general recognition of the need to modernise Madagascar's decayed transport infrastructure if the country is to improve its economic competitiveness and revive the key textile sector.

Roads

There are 37 476 km of roads, of which only 6 103 km are paved, but only 45% are said to be in good condition. The network is highly vulnerable to natural disasters, especially cyclones. Disruption within the network cuts off access to whole regions. There is a move to upgrade the major network to all-weather surfaces. A 105 km length of the RN9 was rehabilitated in 2013–2014. The roads network falls under the Ministry of Public Works (MTP). Road development and maintenance is handled by three units, the Madagascar Roads Authority (ARM), the bridge department and the maintenance department.

In towns, the state of roads is also problematic, as most are cobblestone or gravel and suffer from congestion and poor maintenance. The percentage of rural roads in good condition was only 12% in 2015.

Rail

Madarail is the national railway, which is responsible for the 836 km of rail in the country. The northern line, which connects Antsirable, Amnatondrazaka, Antananarivo and Moranmango to the Port of Toamasina, is operated by Madarail and is only for freight. The fleet and lines have been upgraded over recent years with the help of the World Bank, the European Investment Bank and other commercial banks.

The 163 km Fianarantsoa-Côte Est (FCE) railway in south-east Madagascar connects Fianarantsoa to the port city of Manakara. The line was originally constructed in 1926 and disruptions are common, as a result of broken rails, old rolling stock and landslides caused by cyclones.

The two systems are unconnected. Only a small percentage of freight is carried by rail but, given the condition of the roads, there is a need to upgrade and expand the rail network.

Ports

The largest ports in Madagascar are Toamasina, Mahajanga and the new port of d'Ehola built by QMM and the World Bank in Tolagnaro (previously known as Fort Dauphin) to support the recent ilmenite mining development.

Toamasina handles 95% of the total container traffic. Due to obsolete and unmaintained services, such as cranes and rail infrastructure, it can only handle five 20-foot equivalent units/hour (five TEUs). By comparison, Durban, the busiest of the ports in the region, handles approximately 70 TEUs per hour.

A US$404 million upgrade to the port, funded by the Japanese, will substantially enhance the container-handling capacity and allow it to take much larger vessels. Improved handling facilities should also reduce transit times and allow the port to receive direct calls by container ships, rather than relying on feeder services from hubs in neighbouring states. To take full advantage of the improved facilities, investment in onward infrastructure connections will be needed, such as the planned motorway and modernisation of the rail route to the capital, Antananarivo. It will be necessary to budget for and ensure that skills are in place for ongoing maintenance of the new port and upgraded port and transport network.

The port of Mahajanga has not been maintained for many years, and only has a draft of 4.5 m at high tide.

Airports

Air transport is critical for SIDS. To increase tourism and trade opportunities, the Ivato International Airport in Antananarivo is being upgraded and is due for completion in 2020 and an upgrade to the Fascene International Airport in Nosy Be, was completed during 2018. The upgrades will double the passenger capacity.

Bouygues Bâtiment International and Colas Madagascar have entered into a 50/50 Design-Construction joint venture for the upgrades.

Communications

Telma (Telecom Malagasy) is the national telecom provider, offering a wide variety of phone and internet services. The country has kept pace with telecoms development and is well connected, having taken many major steps as follows:

- **2006:** The first fibre optic lines were installed, and Telma Mobile was launched
- **2008:** The national fibre optic backbone was installed and mobile internet became available
- **2009:** The country's first 3G+ network was introduced, and the island was connected to LION, the first submarine cable connecting to Reunion and Mauritius
- **2010:** Telma connected with EASSy, providing the country with high-speed access via the African continent
- **2010:** Telma launched MVola, the country's first mobile banking service
- **2015:** 4G mobile internet was made available nationwide
- **2016:** The first 4G smartphone was launched
- **2017:** Payment of taxes was made possible via MVola.

Figure 6: Fascene International Airport in Nosy Be after runway strengthening was completed
(Courtesy: Colas Madagascar © Photothèque COLAS)

MADAGASCAR

At present much development is planned or is taking place as follows:

- Telma is expanding the network backbone from 5 000 km to 11 000 km which it hopes to complete by 2019
- The IOX cable should be ready for service in early 2019
- The METISS Indian Oceanic Submarine System cable is expected in 2019
- Wireless broadband access networks are being rolled out, enabling converged voice, data and entertainment services.

Madagascar will also benefit from the development of the Africa-1 cable from South Africa up the east coast of Africa to Saudi Arabia, Egypt and Pakistan which should be commissioned 2020.

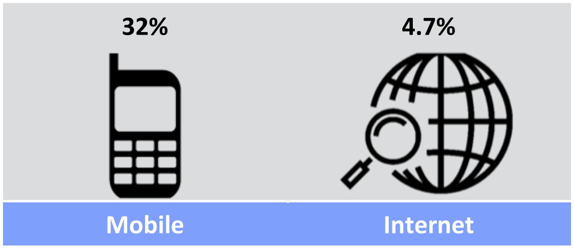


Figure 7: Percentage of population connected to services

There are four mobile network operators, namely Orange Madagascar, Bharti Airtel (formerly Zain), Telma and Blueline.

In 2016 there were 148 585 fixed-line telephones which catered for 0.6% of the population, and 7 998 253 mobile users, representing 32.13% of the total population. Just 4.7% of the population had access to the internet.

TOURISM

In Madagascar, resorts provide their own services, including electricity, water and wastewater treatment. Thus, each resort or hotel chain becomes a mini-town requiring a range of municipal engineering services, and associated professionals.

CONSTRUCTION

Construction is important in any country due to its ability to create jobs and develop skills. This is recognised by President Rajaonarimampianina who is anxious that the construction sector should assist with the revival of the economy by building schools, health care centres, housing stock, motorways, bridges and expanding the ports and airports. This is key to growing agricultural markets and tourism.

Construction in Madagascar costs substantially more than in many other SADC countries, as all raw materials need to be imported, including glass, pipes, conduits, lighting and sanitary fittings, and there are only two local brick manufacturers. Construction has always been dominated by foreign-owned companies, but there are indigenous companies that handle smaller projects. When large public sector contracts are let, partnering with local companies should be mandatory to allow local companies to develop their expertise and grow.

Some of the major projects planned are listed in Table 2, but the country remains highly dependent on financial assistance from international donors. Over the period 2017–2020, US$2 billion of the total donations of US$6.4 billion has been earmarked for the construction of transport infrastructure. Over the past five years limited construction has taken place, with the industry averaging a contribution to the GDP of less than US$400 million per year.

Housing

Housing has not kept pace with urbanisation, and the percentage of the urban population living in slums was reported to be 77.2% in 2014, according to the World Bank. Unemployment and poverty are growing, fuelled in part by an inadequately skilled and unprofessional workforce, and by the lack of an up-to-date strategy for economic development. As a result, entire families crowd the streets of suburbs, living in improvised makeshift shelters.

The processing and disposal of industrial and residential waste is inadequate. Wastewater is often

Table 2: Major projects identified, or being planned or under construction

PROJECT		VALUE US$	START YEAR	END YEAR
Energy	Sahofika hydroplant (192 MW)	~$850m	2019	
	Volobehydroplant (90$ MW)	~$500m		
Water	Wastewater treatment and separation network projects in 9 towns		TBD	
Roads	Road rehabilitation RN13: Tolanaro–Ambovombe		Seeking finance	
	Road rehabilitation RN44		TBD	
	Road upgrade RN2: Antananarivo–Toamasina (240 km)		2018	2021
Other	Toamasina Port upgrades	$404m	2018	2026
	Ivato International Airport upgrade		2017	2020

discharged directly into the city's waterways. Antananarivo is one of the two urban areas in Madagascar where bubonic plague is endemic. These problems were diminished but not eliminated under the mayoral administration of Marc Ravalomanana, who prioritised sanitation, waste collection, security and public administration.

Slums have been portrayed as institutional failures in housing policy, housing finance, public utilities, local governance and secure tenure. This is true of Madagascar where government does not have the funds to develop low-cost housing for the majority of these people. Funding for housing is generally only available from the private sector, usually banks who offer bonds for middle-income families.

LOCAL GOVERNMENT

In 2011, a new urban–rural commune classification was adopted, which resulted in 72 urban communes being formed rather than the previous three-tier provincial, regional and commune structure.

JIRAMA provides water and electricity to urban cities and a few rural regions, while other regions are managed by communes. ARM is responsible for the trunk, regional and district road network. Feeder and local roads are the responsibility of local government. Engineers in local government are responsible for planning all services and ensuring that they are developed. They are also responsible for managing sewage and solid waste removal and for maintaining schools, health centres, markets and public amenities, such as municipal buildings, sports facilities, community halls, cemeteries etc and providing public transport.

Antananarivo's traffic jams are legendry, with bicycles, animal-drawn carts and a single tunnel serving traffic moving from one side of the hill contributing to long journey times. The sprawling slums and inadequate services present further challenges. The Japanese have committed to developing a master plan for the city to offer a long-term structured approach for sustainable development.

Under the umbrella of country partnerships, a programme is envisaged to ensure that 789 000 people in urban areas will gain access to improved urban services. There is a need to strengthen the technical and financial capacity of local government. The Central Administration needs to fund communes until they are able to generate income from servicing the public, industry and the mining sector to become sustainable.

EDUCATION, TRAINING AND PROFESSIONAL DEVELOPMENT

Education and training is a vital part of developing engineering capacity. All elements, from teaching appropriate subjects at schools to continuing professional development (CPD) need to be in place to educate, train and ensure that engineering personnel remain abreast of the latest technology, challenges and emerging solutions.

PRIMARY AND SECONDARY EDUCATION

The schooling system is structured after the French system. Primary education spans five years, while secondary education lasts for seven, made up of two parts, junior secondary of four years and senior secondary of three years. At the end of the junior level, graduates receive a certificate, and at the end of the senior level, they receive the *baccalauréat* (the equivalent of a high school diploma), which is a requirement for entry into higher education.

Historically, education levels in Madagascar have been low. In 1995 more than 40% of children who were of primary school age did not attend school. The Education for All (EFA) Plan was devised to achieve general primary school enrolment and advance the quality and efficiency of the Malagasy educational system. A target of achieving primary education for all by 2015 was set under the Millennium Development Goals. As of 2014, 19% of children of primary school going age were out of school, a great improvement on the status in the 1990s. The challenge remains at higher levels, with 39% not participating in secondary education. Only 2.2% go on to tertiary education.

Due to issues with teacher quality, widespread shortage of materials, overcrowded classrooms and poverty-related obstacles, such as affordability, the

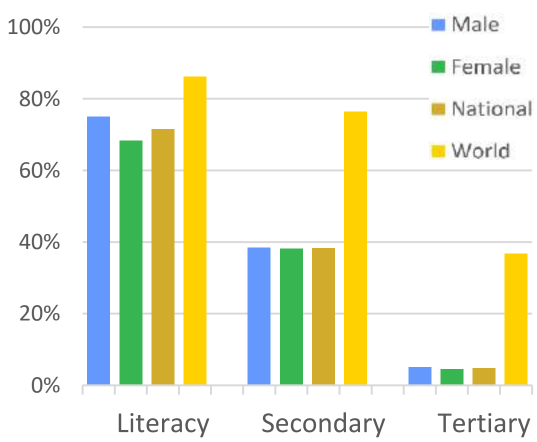


Figure 8: Literacy and enrolment statistics
(UNESCO from 2012 to 2016)

need to work and poor student health, repetition and attrition rates are high. The repetition rate in Grade 3 is a very high 24.5%. Further challenges are the shortage of regular clean water, with 18% of schools not having any running water at all, and the destruction of many schools during each cyclone season.

HIGHER EDUCATION

There are only nine public institutions of higher learning, six universities and three institutes of technology. There are also some 74 private higher education institutions. Those that offer engineering qualifications are shown in Table 3.

The University of Madagascar in Antananarivo was founded in 1961, and set up five provincial branches in Antsiranana, Fianarantsoa, Toamasina, Toliara and Mahajanga. In 1988, each of these became fully fledged universities, three of which have engineering faculties. Faculties are known as Écoles or Institutes. Different faculties offer different subjects. The *Écoles Supérieures Polytechniques* (ESPs) offer engineering qualifications, while the *École Supérieure des Sciences Agro* (ESSA) offers high-level agronomy qualifications. The qualification for agronomist engineers covers agriculture, zootechnics, water and forestry, aquaculture and fisheries, rural socio-economics and the food industry.

The *Institut Halieutique des Sciences Marines* (IHSM) offers marine sciences and the *École Nationale d'Informatique* (ENI) information technology. The *Instituts Supérieurs de Technologie* (ISTs) were instituted to offer professionalised qualifications, including engineering.

Private institutions have continued to open since legislation made this possible. In 2014, there were 51 private institutions accredited, four provisionally accredited and 19 that had applied for accreditation. Several only enrolled small numbers of engineering students for the first time in 2014 and few of these have completed their studies. These institutions are not shown in Table 3. None of the private universities is recognised by the Order of Malagasy Engineers (OIM), as indicated in the second column of Table 3.

The higher education system is based on the Bologna Process 'LMD' structure, Licentiate, Master's and Doctorate. The LMD system has been adopted throughout the EU and further afield as it establishes degree equivalence between one university or higher education system and another, allowing students to transfer credits and facilitating international student mobility. The first two years of the licentiate are largely general mathematical and scientific theory, and in the third year, applied subjects are introduced. The Master's is composed of a one-year industrial attachment, followed by another year of theory.

Students may leave after three years, at which stage the graduate receives a Licentiate and works as a technician. After completing five years of study, the student graduates with a Master's and is known as an engineer. It is possible for technicians to return at any stage and continue studies towards graduating as an engineer, but few technicians return, and often students on industrial attachment do not return, rather remaining in the employ of the host company. Many employers discourage technicians from returning to complete their Master's as they can then command higher salaries. As a result, the overall throughput in terms of engineers is only 10%, which is costly to the nation.

It was not possible to gather historical data from all institutions. The data shown in Table 3 is a combination of a snapshot gained from the Ministry's 2014 Annual Report and historical data supplied by the four main institutions offering engineering qualifications.

Figure 9 and Figure 10 relate to data from the latter four only, which shows the general trend of an increase in engineering graduations. Graduation by institution and category is shown in Figure 9 and the split by discipline, category and gender is shown in Figure 10.

In the case of new institutions, when data for only one qualification was given, but the report showed that more qualifications were offered, they are indicated with a tick. Several are considering adding more qualifications, but the subjects and expected numbers were not yet known.

Funding for higher education is limited, with some engineering departments reporting academic vacancy levels as high as 40%. It would seem that salaries are very low, making it difficult to attract high-calibre academics. Industry advises that they prefer to employ students from private universities, even if they are not recognised by the OIM, because private institutions are able to pay higher salaries and attract more, or better-qualified, academics. Laboratories and equipment are also outdated in many established institutions.

Table 3: Engineering graduations in Madagascar in 2014

INSTITUTION	Recognised by OIM	Agricultural & Fisheries	Chemical	Civil	Electrical, Electronics, & Telecoms	Industrial	Informatics	Mechanical & Electromechanics	Mining & Metallurgy
Public institutions									
Engineering degrees									
Université d'Antsiranana – École Supérieure Polytechnique d'Antsiranana (ESPA-D)	Y			19	47			24	
Université d'Antananarivo – École Supérieure Polytechnique d'Antananarivo (ESPA-T)	Y		24	193	100	23			79
Université d'Antananarivo – École Supérieur des Sciences Agronomiques (ESSA)	Y	44							
Université de Fianarantsoa – École Nationale d'Informatique (ENI)	Y						91		
Université de Toliara – Institut Halieutique et des Sciences Marines (IHSM)	Y	17							
Engineering diplomas									
Université d'Antananarivo – École Supérieure Polytechnique d'Antananarivo (ESPA-T)	Y		19	139	98	53			89
Institut Supérieur de Technologie d'Antananarivo (IST-T)	Y			72					
Institut Supérieur de Technologie d'Antsiranana (IST-D)	Y					34			
Private institutions									
Engineering degrees									
Espace Universitaire Régional de l'Océan Indien (EUROI)	N				24				
Hautes Etudes Chrétienne de Management de Mathématiques Appliquées (HECMMA)	N			28		6			
Institut de Formation Technique (IFT)	N			25					
Institut Supérieur Polytechnique de Madagascar (ISPM) (Antananarivo)	N			45	29			27	
Institut Supérieure (IS)	N			10	41				
Engineering diplomas									
Université U-MAQIS École Professionnelle Supérieure Agricole (EPSA)	N	38							
Université U-MAQIS École Supérieure de Bâtiments et Travaux Publics (ESBTP)	N			40					
Université U-MAQIS Etablissement Technique Supérieur (ETS)	N							11	
Institut Supérieure d'Ingenierie Technologie et Management (ISITM)	N			10					
Institut Universitaire Polytechnique de Madagascar (ISM)	N			12					
Institut Supérieur Polytechnique de Madagascar (ISPM) (Antananarivo)	N		20	√			√	√	
Université Génius System Informatics (GSI)	N			10					
Etablissement Technique de Formation Professionnelle Supérieure (ETFPS)	N							40	
Université Privé Hay Soa (UPHS)	N			9					
École Supérieure des Metiers et des Arts Plastiques (ESMAP)	N			34					
Institut de Formation Technique (IFT) (Mahajanga)	N			7					
Institut de Formation Technique (IFT) (Antsirabe)	N			8					
Institut de Formation Technique (IFT) (Toamasina)	N			14					
TOTAL									
Five-year degree (896)		61	24	320	241	29	91	51	79
Three-year qualification (757)		38	39	355	98	87	0	51	89

MADAGASCAR

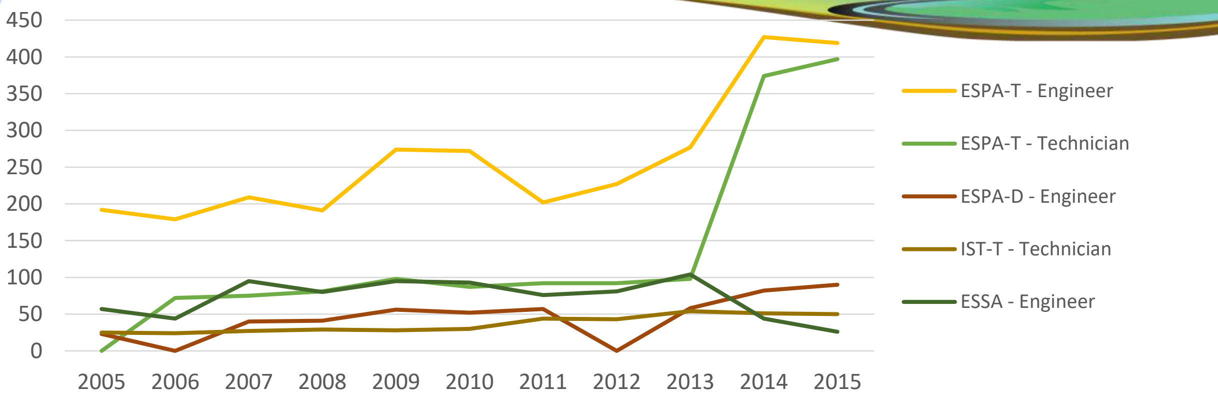


Figure 9: Engineering graduates by institution and category

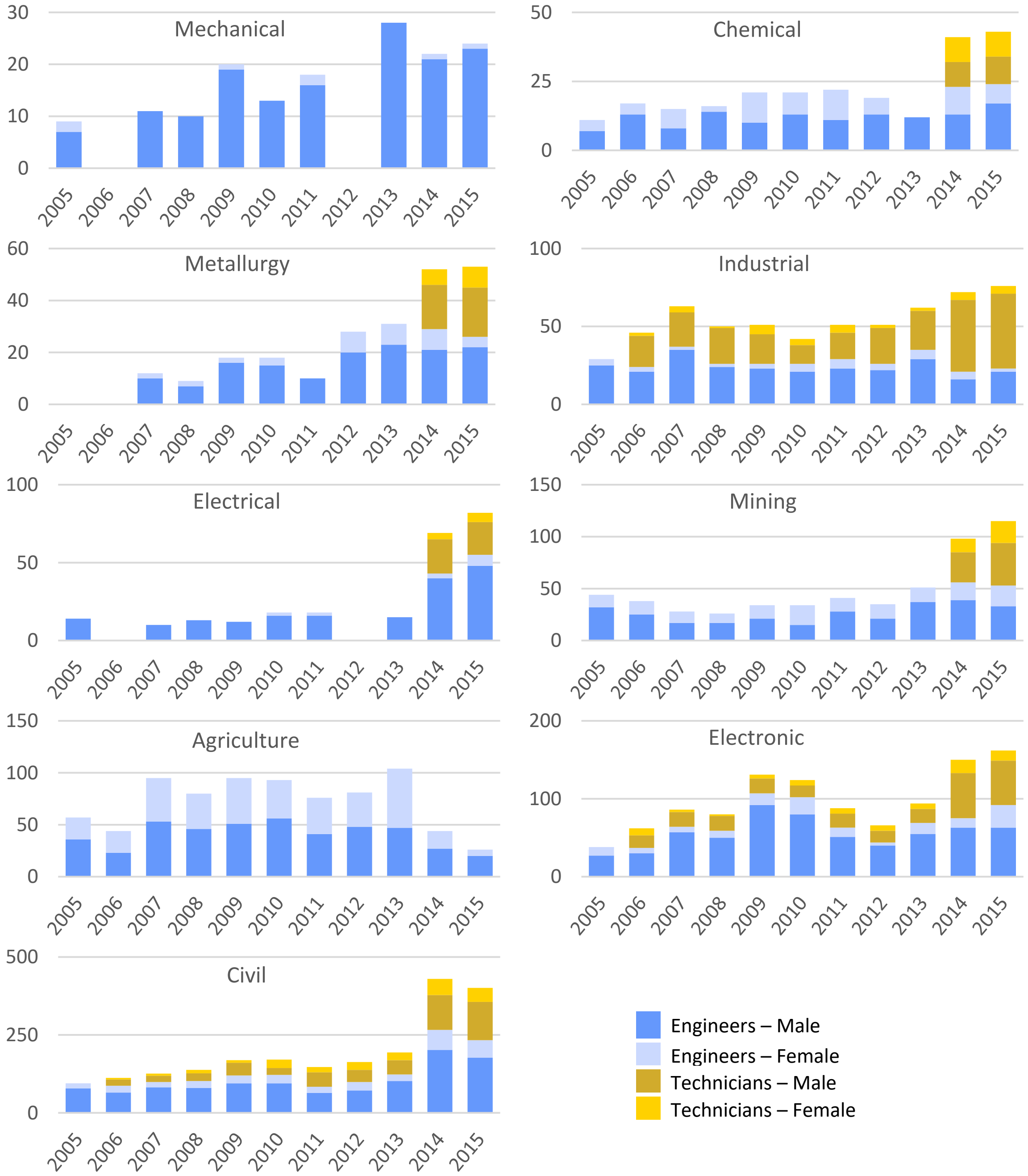


Figure 10: Engineering graduates by discipline, category and gender for selected institutions as per Figure 9

Academics and employers expressed many concerns about out-of-date curricula and teaching methods. With outdated equipment, teaching modern methods and processes presents a problem. Much courseware is still based on post-war French content, with limited reference to local conditions and solutions. In some instances, British design codes are used. A project with Edinburgh University commenced in mid-2018 to develop structural engineering codes relevant to local materials and conditions.

Teaching methods that recognise the learning needs of the Millennial generation must be adopted. The private universities are said to pay more attention to establishing principles, teaching problem-solving, developing the individual, and building self-confidence, communication and management skills. Private universities also interact with industry to get input on the relevance of their courses and to find work placement opportunities.

Long strikes at government universities and closure due to bubonic plague in 2017 have also affected student output.

Accreditation

Accreditation is a three-step process, requiring an agreement to be in place, followed by receipt and approval of the curriculum, and thereafter the resourcing schedules, including details of teaching staff and facilities. Qualifications are accredited by the Ministry of Higher Education and Scientific Research which seeks input from engineering professionals for engineering qualifications. To date, no private universities have been accredited. International norms such as the Washington and Dublin Accords are not considered by the Ministry in this process.

To ensure that they maintain high standards, the *Institut Supérieur de Technologie d'Antananarivo* (IST-T), working with the *Francophonie Institute for University Governance* (IFGU), follows the self-evaluation process developed by CAMES, the *Conseil Africain et Malgache pour l'Enseignement Supérieur* (African and Malagasy Council for Higher Education). CAMES represents 17 francophone African states and aims to enhance mutual recognition of qualifications and to promote professional and student mobility between its members. The IST satisfied the requirements of CAMES and its accreditation was renewed in January 2017.

Student mobility

In 2015, a total of 47 Madagascan students were studying at South African universities, of whom 10 were studying by correspondence through the University of South Africa. However, only one student from Madagascar has graduated with an engineering qualification since 2005 – gaining a national diploma from the Cape Peninsula University of Technology in 2014. Students from the Comoros make up the bulk of foreign students studying engineering in Madagascar, and others also come from francophone African states.

The government grants scholarships for studies abroad, with students generally studying in France, other European countries and China. Scholarship holders are expected to return to work in Madagascar, some for as long as 10 years, depending on the disciplines and conditions of award.

GRADUATE TRAINING

Once the tertiary education phase is complete, it is necessary for graduates to receive structured training in the workplace, under professional supervision and mentorship, to develop to the level of competence required for professional registration, and to be able to take on work independently. Many of the voluntary associations discussed below list graduate support as part of their mandate. The OIM is considering developing a structured programme to guide graduates and companies.

Graduates struggle to find employment, but the departments and companies visited that do take graduates reported having some sort of graduate training system in place. Due to the poor state of the economy, engineering staff of all ages appear to struggle to find work and will accept any post in an engineering company in the hope that they will be placed in an engineering post when it becomes vacant. Many engineers are said to be working at technician level, simply to have a job.

PROFESSIONAL REGISTRATION

On 6 September 1995, Law No. 95-024 was passed, addressing professional engineers and consulting engineers and the creation of the Order of Malagasy Engineers (OIM). The OIM was formed to draw on engineers nationwide to contribute to sustainable development and revival of the economy. The OIM's activities are divided into three areas:

- A political and strategic focus with respect to ethical behaviour of engineers and clients
- A socio-economic focus of developing an integrated vision with all stakeholders
- Know-how and training to grow the multi-disciplinary skills of engineers.

Table 4: OIM registration statistics in November 2018

SECTOR	NUMBER
Agriculture	171
Mechanical	42
Civil	298
Chemical	60
Electrical	16
Electronic	33
Industrial	63
ICT	38
Mining	44
TOTAL	**765**

Charles Rakotonirina, the first OIM President, strongly believed that the country needed engineers to support continuous development to allow the economy to grow. There were 765 professionals registered by the OIM in November 2018 as shown in Table 4.

The OIM registers graduates with recognised engineering qualifications once they have completed a year in formal engineering employment. This is different from the situation in other SADC countries where professional registration is based on competency in the workplace rather than time in the workplace. There are plans to introduce competency-based professional registration to align with the International Engineering Alliance approach.

VOLUNTARY ASSOCIATIONS AND CONTINUING PROFESSIONAL DEVELOPMENT (CPD)

There are numerous voluntary associations offering support in Madagascar, all of which fall under the Federation of Engineering Organisations (or the *Fédération Nationale des Organisation d'Ingénieurs Malagasy* (FNOIM)). The associations listed in Table 5 are loose interest groups which share knowledge and offer support to graduates where possible.

There are other engineering bodies that do not fall under the FNOIM, such as the Union of Agricultural Engineers of Madagascar (*le Syndicat des Ingénieurs Agronomes de Madagascar* (SIAM)) and the Association of Engineers for the Development of Renewable Energy (AIDER).

Many NGOs also offer training and support in relation to the provision of water, improved sanitation, waste management and improved agricultural productivity. It is estimated that several hundred engineers and technicians are employed in this sector.

With this large number of interest groups and specialisations, the government should rely heavily on the engineering community for input and strategic direction. Unfortunately, it seems that the environment does not lend itself to civil society involvement. In the interests of the public, the engineering community needs to take the lead, set standards, contribute to the development of policies and play a role in monitoring performance and ensuring remedial action where required.

Table 5: Voluntary engineering associations falling under the FNOIM

ACRONYM	ASSOCIATION
AFIM	Association of Malagasy Women Engineers
AIAM	Association of Agricultural Engineers in Madagascar
AIGETO	Association of Topographic Land Surveyor Engineers
AIHSPA	Hydraulic Association of Engineers of the Polytechnic College of Antananarivo
AIIG	Association of Engineers in Geographical Information
AIIM	Association of Malagasy Computer Engineers
AIM	Association of Malagasy Engineers
AIMIMA	Association of Mining Engineers in Madagascar
AIPM	Association of Engineers in Oil in Madagascar
AISEA	Association of Engineers in the Water and Purification Sector
AITM	Association of Engineers in Telecommunications in Madagascar
AMIEF	Association of Water and Forestry Engineers
AMIS	Malagasy Association of Statistical Engineers
AZISPAM	Association of the Zoological Technicians and Engineers Specialised in Animal Production in Madagascar
EMSA	Engineers Master of Science Association
FIAVAMA	Association of Building and Public Works Engineers Malagasy
GIE	Group of Entrepreneurial Engineers (Association of Consulting Engineers)
GIST	Group of Engineers in the Transport Sector
SIEEM	Labour Union of Electrical and Electromechanical Engineers in Madagascar
SNIERM	National Labour Union of Malagasy Equipment Engineers
UIMM	Union of Engineers in Meteorology in Madagascar
UNICITY	National Union of Chemical Engineers and Engineers of Industrial Techniques
UNMG	Malagasy National Union of Geologists

To support the many institutions to become more visible to interested members and those who need to use engineering services, the Royal Academy of Engineering has made funding available from the Newton Fund to develop and update the websites, activities and event management systems of these organisations.

WOMEN IN ENGINEERING

The Association of Malagasy Women Engineers (*Association des Femmes Ingénieurs Malgache (*AFIM)) was set up to encourage and support women entering engineering. The organisation is still in its infancy with only some 20 or 30 in the group, although the OIM reports an impressive 23% of female registrations, as can be seen in Figure 11.

THE WORKFORCE

Although it is estimated that some 5 000 to 6 000 engineers have graduated over the past 40 years, there are possibly only 3 000 to 4 000 working in engineering as a result of losses such as retirement, mortality, emigration and those moving into non-engineering sectors. The number of technicians employed is estimated to be around 8 000 to 9 000, although there are many more working in other fields due to the difficulty in finding work.

The profile of membership of the OIM, shown in Figure 11, reflects the ongoing political instability and periods of negative growth in the economy.

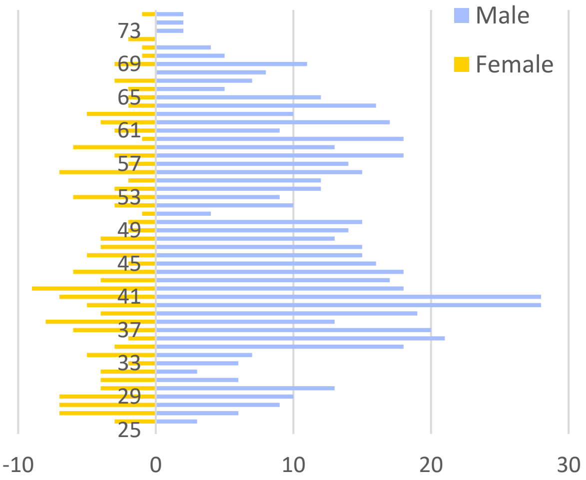


Figure 11: Membership of the OIM by age and gender

THE PRIVATE SECTOR

The main employers in the private sector are consulting, contracting, manufacturing, supplier and mining companies. Lower numbers are employed in small entrepreneurial companies, training organisations and others where engineering input is required.

There are also many NGOs assisting with social infrastructure, rural development and enhancing farming methods. Due to the limited employment opportunities in the formal sector, many engineers become entrepreneurs and create opportunities by making small volumes of specialist products which they sell within their own locality, or earn a living offering advisory services, often on a *pro bono* basis, until they are able to find a client willing to pay for their expertise.

Consulting

There is no registration board or council which regulates consulting practices. There are only about five substantial consulting companies, each employing between 10 and 50 staff, most of which are subsidiaries of international companies. Furthermore, there are many local engineers working on their own to provide consulting services on small projects. Most international companies consider the political`- environment too unstable for setting up local offices and carry out consulting work from branch offices in nearby countries or further afield.

Designs done outside the country are not vetted by locals in terms of suitability and recognition of local conditions. Regrettably, Madagascar does not have a full set of local design codes and standards to enforce, hence designs are often done in accordance with the funder country's codes and standards. Given the cyclonic conditions, the nature of the soil and many other unique variables, there is a need to develop a suite of local standards, the use of which should be enforced on all contracts. As a start, the University of Edinburgh is assisting with the development of local structural codes.

Contracting

There are about 2 000 contractors in Madagascar, however, the sector is largely informal and unregulated. The majority are micro companies owned by individuals who often do not have construction experience. Ministries complain of the poor quality of work delivered due to the inadequacy of staff and construction methods used.

There are about 200 contractors with some substance, the major companies being foreign. To be awarded large or long-term contracts it is necessary to register a subsidiary locally. Colas Madagascar is the largest locally based contractor and has served the country for more than 60 years. It is estimated that there about 20 international companies who develop infrastructure financed by donors. The requirement that foreign companies should employ and train Malagasy nationals is honoured by some contractors but locals complain of contracting staff being brought into the country for major projects – not only professionals, but labour too. Dedicated construction legislation similar to that in place for the mining industry should be considered.

The interests of contractors are served by the Union of Building and Public Works Contractors (*le Syndicat des Entrepreneurs du Batiment et des Travaux Publics* (SEBTP)).

Manufacturing

In 2014, there were just over 600 companies offering formal employment to 263 000 people in the manufacturing sector. Considering the large numbers employed in the food and beverage sector, it is estimated that manufacturing employs over 3 000 engineering practitioners as a whole.

The Ministry of Industry and Private Sector Development is tasked with fostering economic growth by promoting trade and investment. Various private sector associations represent the interests of manufacturers and the business community, including the FIV.MPA.MA (*Association des Investisseurs et Industriels Malagasy*). The *Cercle de Réflexion des Économistes de Madagascar* (CREM) is a non-profit thought-leadership group which develops and publishes policy and economic proposals to address economic growth. It contributes to research and recommendations in terms of the growth of the manufacturing sector from time to time, in partnership with *the Syndicat des Industries de Madagascar* (SIM).

Mining

In 2014, there were 168 companies formally employing about 12 500 people in the mining sector. The companies were involved in small-scale and large-scale mining, quarrying and exploration. This excluded the hundreds of thousands of artisanal miners involved in the collection of gemstones. As production at QIMM, Ambatovy and Kroama Mines has since increased, this number would have increased, possibly to about 14 000.

The Mining Investment Act (*Loi sur les Grands Investissements Miniers* (LGIM)) requires that mining companies prioritise the employment and training of Malagasy nationals. In 2014, Ambatovy Mine employed 84% and QIMM Mine 94% nationals. Of the foreign nationals employed, many are engineers, employed from mining countries such as Canada and South Africa to get operations going and to train locals. They have, however, expressed concern about the standard of the Malagasy engineering degrees, commenting that local engineers do not appear to have received the level of theoretical and problem-solving training expected of degrees recognised by the Washington Accord. As a result, local engineers are more comfortable with following processes than with planning and playing strategic roles.

The interests of the mining sector are served by the Chamber of Mines and mining engineers are represented by the *Association des Ingénieurs des Mines de Madagascar* (AIMIMA).

Agriculture

Due to the dependence on agriculture, agricultural engineers play a key role in the private sector, the government, in research and in the employ of NGOs. In 2016, 877 agronomic engineers belonged to the *Syndicat des Ingeniéurs Agronomes de Madagascar* (SIAM). The number of engineers in government continues to decrease due to the moratorium on employment.

These engineers are involved in breeding, production, fisheries and water resource management, and focus on planning and designing techniques and technologies to increase production and improve productivity. Agricultural engineers have had many successes at introducing innovations, but there are simply not enough of them, given the number of smallholders and the extent of farming. About 80 agricultural engineers graduate each year. More are required, but the value of agricultural engineers is not recognised and utilised to the full, thus increasing the number would not be practical at this stage due to the lack of job opportunities in the sector. Those working in the sector complain of heavy workloads.

THE PUBLIC SECTOR

Many engineering practitioners are employed in the public sector, the largest numbers being employed in the structures listed in Table 6. Sadly, there has been a moratorium on employing staff in the public sector for many years and the numbers are steadily dropping. Those interviewed advised that they did not have specialists in many areas and, in some instances, had to use the services of international consultants. Examples cited included the lack of bridge engineers and those with port experience.

Salaries were said to be extremely low, making it difficult to retain mid-career staff. Engineers expressed frustration with not being involved in policy- and decision-making processes. A collaboration platform was needed to allow private and public-sector engineers and decision-makers to work together to develop sustainable solutions.

Table 6: Ministries employing engineering practitioners

MINISTRIES/STRUCTURES
Ministry of State for Infrastructure and Spatial Planning – *Ministère d'Etat chargé des Projets Présidentiels et de l'Aménagement du Territoire*
Ministry to the Presidency of Mines and Petroleum – *Ministère chargé des Mines et du Pétrole auprès de la Présidence*
Ministry of Interior and Decentralization – *Ministère de l'Interieur et de la Decentralisation* • Provinces, cities, municipalities and communes
Ministry of Agriculture and Rural Development – *Ministère de l'Agriculture et du Développement Rural*
Ministry of National Defence – *Ministère de la Défense Nationale*
Ministry of Economy and Planning – *Ministère de l'Economie et de la Planification*
Ministry of Energy and Hydrocarbons – MEH (*Ministère de l'Energie et des Hydrocarbures*) • Agency for the Development of Rural Electrification – ADER (*Agence pour le Développement de l'Electrification Rurale*) • The National Fund for Electricity – FNE (*Fond National de l'Electricité*) • The Electricity Regulatory Body – ORE (*Office de Regulation de l'Electricité*) • Hydrocarbons Office – OMH (*Office Malagasy des Hydrocarbures*) • The Economic Development Board of Madagascar – EDBM (*Conseil de Développement Economique de Madagascar*) • The National Power and Water Utility – JIRAMA (*Jiro sy Rano Malagasy - Compagnie Nationale d'Eau et d'Electricité de Madagascar*)
Ministry of Industry and Private Sector Development – MIDSP (*Ministère de l'Industrie et du Développement du Secteur Privé*)
Ministry of Water, Hygiene and Sanitation – *Ministère de l'Eau, de l'Hygiène et de l'Assainissement*
Ministry Posts, Telecommunications and New Technologies – *Ministère des Postes, Télécommunications et Nouvelles Technologies* • Telecommunications of Madagascar – TELMA (*Telecommunications de Madagascar*)
Ministry of Public Works – *Ministère des Travaux Publics* • Madagascar Roads Authority – ARM (*Autorité Routière de Madagascar*) • Department of Bridges and Roadways • Department of Road Maintenance
Ministry of Higher Education and Scientific Research – *Ministère de l'Enseignement Supérieur et de la Recherche Scientifique*
Ministry of Tourism, Transport and Meteorology – *Ministère du Tourisme, des Transports et de la Météorologie* • Fianarantsoa–East Coast Line – FCE (Ligne Fianarantsoa–Côte Est) • Air Madagascar • Civil Aviation Authority of Madagascar – Aviation civile de Madagascar • Toamasina Autonomous Port – SPAT (Société du Port à gestion Autonome de Toamasina) • Maritime and Fluvial Port Agency – APMF (Agence Portuaire Maritime et Fluviale) • QIT Madagascar Minerals (QMM) for the Port of Taolagnaro – QIT Madagascar Minerals pour le Port de Taolagnaro • Antalaha Lifting and Handling Company – SAMA (Société d'Acconage et de Manutention d'Antalaha)

MIGRATION TRENDS

Analysis of the United Nations Population Division statistics for 2015 shows a net loss of professionals from Madagascar. Of those entering the country, 40% were from the Comoros. Emigrations were to France, Reunion, the Wallis and Futuna Islands, Mauritius and the Seychelles.

These figures refer only to those who officially emigrated or immigrated. There is ongoing movement of engineering professionals as projects are awarded to international companies.

ENGINEERING NUMBERS AND NEEDS

Combining all the data, it would seem that there are approximately 11 000 engineering practitioners in Madagascar, as detailed in Table 7. Considering all the developments needed, there is clearly a need for more qualified and well-experienced engineering practitioners, but not until meaningful investments have been committed to develop new and upgrade existing infrastructure.

In 2015, 900 engineers and 760 technicians graduated. By 2019, it is estimated that an additional 120 will graduate from new qualifications. Figure 12 shows the current workforce, the losses that will occur over the 18-year period to 2035 due to retirement, mobility and mortality, and the growth in engineering capacity if local engineering graduations increase at 2% per year over the period.

Table 7: Estimated numbers of engineering practitioners in the engineering workforce

SECTOR	ESTIMATED NUMBER
Academia and research	700
Agriculture	1 000
Consulting	400
Contracting	1 000
Government	1 850
IT, systems and telecommunications	700
Manufacturers and suppliers	3 500
Mining	750
Miscellaneous and NGOs	1 100
TOTAL	**11 000**

MADAGASCAR

The blue dotted line shows the growth in skills that would be required at the 2017 GDP growth rate of 4.2% and the green dotted line shows the growth based on the 2018-2023 GDP projection of 5.1%. A 70% employment elasticity factor has been used to extrapolate the employment demand.*1

With the increase in numbers emerging from private institutions, and the limited investment in industry and infrastructure development, the number being trained will continue to exceed the demand regardless of the growth projections used. Given the fact that public structures need to be capacitated, the manufacturing sector needs to expand, and local engineering practitioners should eventually be the main players in consulting and contracting, there is an urgent need to offer graduates comprehensive workplace training to develop as professionals.

The private sector needs to be incentivised to train graduates and the public sector needs to take them on. It is also important that all public sector tenders should include graduate training conditions, which must be monitored and enforced.

Consideration needs to be given to rationalising the higher education offerings to ensure that a more appropriate numbers of graduates and improved quality emerge.

When reviewing the numbers required, consideration should be given to increasing the number of studying chemical engineering as they are critical for agro-processing, in power generation and in the petrochemical sector, among others.

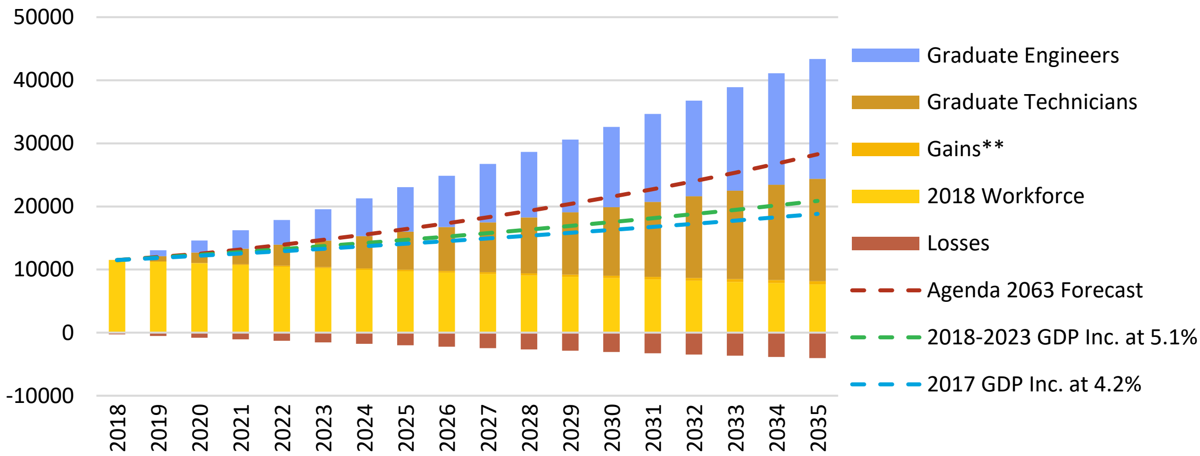


Figure 12: Flow of engineering skills based on a 2% increase in graduation rate per year

***Excludes international engineering practitioners in the country on short-term contracts*

KEY RECOMMENDATIONS

To develop a sound pool of engineering professionals, able to contribute to the well-being of Madagascar, the following should be considered:

Schooling

- **Primary and secondary education:** Address the weaknesses in primary and secondary education, and increase the number completing secondary education with acceptable results.
- **Career guidance:** Expand career guidance to attract high-calibre entrants into the engineering profession, incorporating programmes to reach female learners, and rural and low-income areas.
- **Bursaries:** Provide bursaries to attract those with good mathematics and science passes to study engineering.

Higher education

- **Consolidation:** Consolidate engineering studies into well-resourced universities and institutes to ensure quality output.
- **Accreditation:** Develop a rigorous national accreditation programme in collaboration with OIM to ensure the quality of engineering education using the guidelines of the Washington and Dublin Accords or

*[1] Employment elasticity is a measure of the percentage change in employment associated with a 1% change in economic growth. If the growth is likely to be in agriculture, the percentage could be lower, as growth in that sector is generally to do with productivity gains and not employment, while if the growth is likely to be in high tech manufacturing, the elasticity factor maybe more than 100%.

alternatively, consider using the accreditation guidelines of the European Network for Accreditation of Engineering Education (ENAEE).
  - Encourage institutions to develop adequate complex engineering problem-solving content and graduate attributes to satisfy the requirements of the Accords.
  - Ensure that qualifications offered by private higher education institutions are accredited and recognised by the OIM and enhance or withdraw those which do not meet the requirements.
- **Industry liaison:** Liaise with industry on a regular basis to ensure that curricula, methods, software and equipment are relevant and up to date.
- **Curricula:** Provide funding to research, modernise or develop curricula and material where required.
- **Facilities:** Raise funding to upgrade lecture theatres, libraries and laboratory facilities where required.
- **Resources:** Raise funding for computers, engineering software, access to online reference material, and laboratory and other equipment, and ensure adequate support to offer technology-relevant training.
- **Attract and retain academics:** Improve conditions of service, support and packages to attract, retain and appoint additional academics.
- **Teaching methods:** Apply the latest methods and technology for teaching and train academics in 21st century approaches to teaching.
- **Academic development:** Provide funding for lecturer post-graduate development and facilitate opportunities for academics to gain experience in industry.

Graduate training

- **Develop programmes:** Develop national graduate training programmes to ensure graduates achieve the level of competence required by industry and for professional registration.
- **Private sector incentives:** Offer tax rebates or incentives for private sector companies to develop graduates.
- **Public sector support:** Ensure that public sector structures take on and train graduates and that they are absorbed and developed through the ranks.
- **Institutional support:** Institutionalise graduate training in all organisations by setting KPIs for experienced staff to act as supervisors and mentors.
- **Project support:** Make graduate training a requirement of all public sector projects and ensure that the progress of graduates is monitored, and penalties are imposed for non-compliance.

Registration of engineering professionals

- **Registration:** The OIM to develop a more rigorous registration process to assess competence in the workplace, rather than registering professionals based on time spent in the workplace.
- **VAs:** Recognise and support the development of voluntary associations in the engineering sector.

Continuing development

- **CPD:** Fund the development of a robust CPD system, monitored by the OIM but rolled out by the various voluntary associations and higher education institutions, to include courses, workshops, conferences, online learning etc.
- **Validation:** Validate short courses and skills programmes for a specified period only to ensure that training remains up to date and relevant.
- **Post-graduate studies:** Provide post-graduate bursaries to develop specialists in various fields, such as geotechnical, structural, harbour and coastal engineering, and link them to specialist consultants to assist them with practical application.
- **Develop managers and leaders:** Encourage industry to continue investing in graduates after professional registration to grow management and leadership capabilities.

Registration of service providers

- **Legislation:** Consider developing a National Construction Industry Act to:
  - Cover the increasing use of local consultants, contractors, labour, plant and materials.
  - Ensure that foreign consultants and contractors partner with local companies.
  - Ensure that there are requirements for consultants and contractors to train graduates, artisans and other construction-related skills.
  - Ensure local contractors are developed as part of large projects.
  - Ensure that international consultants provide all calculations, drawings, operating manuals and other reference material in French.
  - Ensure that local consultants, along with the client, check that design proposals address local needs and customs and that design calculations comply with national codes and standards.

  - Limit companies to a certain size or category of work based on their technical skills, past experience and the availability of plant and capital.
- **Quality:** Implement quality assurance on all projects and ensure penalties are imposed for poor performance.

Public sector

- **Economic infrastructure:** Invest in the development of economic infrastructure such as electricity, roads, rail, ports and airports, and address the supply of water services.
- **Maintenance:** Invest in maintenance to preserve new infrastructure and prevent further deterioration of existing infrastructure.
- **Tariffs and payment:** Review and increase tariffs where appropriate, and enhance domestic revenue collection and demand management to fund development.
- **Codes and standards:** Develop local engineering codes and standards for the design of engineering infrastructure where required.
- **Technical capacity:** Reprioritise budgets to fill vacancies, build technical capacity, ensure that salaries are competitive and develop succession plans to make the public sector an employer of choice.
- **Technical decision-makers:** Ensure that engineers are employed in senior decision-making posts.

Industry-wide collaboration

- **Advisory team:** Set up an engineering advisory team, recognised by government, to advise on and endorse infrastructure development proposals, tertiary curricula and graduate training programmes.
- **Collaboration:** Encourage all professional bodies to work together to share knowledge, exchange best practice and ensure coordinated planning of industry support initiatives.

ACKNOWLEDGEMENTS

The detailed picture presented would not have been possible without the support of academics, various professional bodies, government departments and many passionate engineers. A big thank you to Mamy Rabenanahary for setting up all the appointments and assisting with research meetings. Thank you to academics Dr Jean Lalaina Rakotomalala, Dr Zarasoa Arnole Rasolomampionona, Rado Ralaitahina and Harinaivo Ramanantoanina for making data available and offering insight into the higher education system.

Thank you Haja Rabiarivelo from JIRAMA, Thierry Razafindrakoto from TELMA, Heri Razafimahefa from the Antananarivo Municipality, Dr Tsiry Angelos from the JB Group, Hery Rakotomanantsoa, Hery Rakotovao, Jules Randriamanatena, Bruno Ramamonjiso, Charles Rakotonirina, Victor Razanadrakoto, Lovy Rasolofomanana and Mamiharilala Rasolojaona for always being willing to assist and offering lots of input.

SOURCES OF INFORMATION

Data and information were gathered during meetings, interviews and telephone conversations, and via email and Skype. SADC reports, master plans and strategies as listed under *Plans and Strategies*, and many standard international sets of data as listed in Chapter 5, *Research Approach,* were also consulted. Comprehensive documents focusing on specific issues in Madagascar as listed below were additional sources of information.

Breuil, C. and Grima, D. 2014. *Baseline Report Madagascar*. SmartFish Programme of the Indian Ocean Commission, Fisheries Management FAO component. Ebène, Mauritius.

CREM (Cercle de Réflexion des Économistes de Madagascar). 2016. *Poids des Entreprises Industrielles Membres du SIM dans l'economie Malgache.* Antananarivo.

Direction des Grandes Entreprises, Vice-Primature chargée de l'Economie et de l'Industrie. 2012. *Les 100 Premieres Entreprises de Madagascar par Chiffre D'affaire. Decroissant par Secteur D'activite*. Antananarivo.

JE Austin and Associates. 1991. *Madagascar: The role of the private sector.* Washington, DC.

Ministère de l'Enseignement Supérieur et de la Recherche Scientifique (MESupReS). *Annuaire Statistique* 2013–2014. Antananarivo.

Morris, M. and Sedowski, L. 2009. The competitive dynamics of the clothing industry in Madagascar in the post-MFA environment. In McCormick, D., Kuzilwa, J.A. and Gebre Egzibher, T. (Eds). *Industrialising Africa in the Era of Globalisation: Challenges to Footwear.* Nairobi: University of Nairobi Press.

OMNIS, Madagascar Ministry of Energy. 2016. *Madagascar on the road to stability and development*. Antananarivo.

Pigaht, M. And Werler, S. 2016. Madagascar: Opportunities for solar business. Berlin: Deutsche Gesellschaft für Internationale Zusammenarbeit GmbH (GIZ).

U.S. & Foreign Commercial Service and U.S. Department of State. 2015. *Doing business in Madagascar: 2015 Country Commercial Guide for U.S. Companies.* Washington, DC.

World Bank Group. 2014. *Economic contributions from industrial mining in Madagascar*. Washington, DC.

World Bank Group. 2017. Country Partnership Framework for the Republic of Madagascar for the period FY17–FY21. Washington, DC.

MALAWI

MALAWI is a landlocked country bordered by Zambia to the northwest, Tanzania to the northeast, and Mozambique on the east, south and west. Lake Malawi takes up a third of the country's area.

Malawi is among the world's least-developed countries. The economy is heavily based in agriculture, with a largely rural population. It is the third most densely populated country in the SADC region, with 157 people per square kilometre in 2017, limiting the availability of land to support growth and development of rural communities.

More than 71% of Malawians live below the international poverty line with 89% of employed persons being in informal employment in 2013. In 2017, the HIV/AIDS prevalence rate was estimated at 5.8%.

Lilongwe is the capital city and Blantyre is the commercial and manufacturing capital. There are two other cities: Zomba, the former capital, now a university town and Mzuzu, in the north, famed for its tea and coffee.

Urbanisation has been on the increase because of declining earnings from small-scale farming due to population growth and lack of agricultural inputs to promote intensive farming methods. This has led to a growth in urban poverty with homeless migrants and others living in slums and squatter settlements.

THE ECONOMY

The economy which has traditionally been based on agriculture, remains undiversified and vulnerable to external shocks such a drought, floods, world food prices and corruption, amongst others. As a result, the inflation rate, has remained high since 2011, dropping to single digits for the first time towards the end of 2017, in anticipation of a good maize harvest.

Economic growth is also hindered by high transport costs, lack of skilled labour, and inadequate and deteriorating road, electricity, water, and telecommunications infrastructure. In 2017 it earned the lowest GDP per capita in the SADC region.

As Malawi is a beneficiary under the African Growth and Opportunity Act (AGOA), this has allowed local products to enter the USA market duty-free. This has contributed some US$50 million per year to exports, which could be increased with enhanced small and medium enterprise (SME) support and production.

PLANS AND STRATEGIES

To address the challenges outlined, there are several important plans and development policies in place, the most important of which are the:

- **National Development Strategy (1997–2020)** incorporating Vision 2020 which is a framework for preparing medium-term plans to work towards becoming a middle-income economy.
- **Malawi Growth and Development Strategy (MGDS) III (2017–2022)** aimed at building a productive, competitive and resilient nation.
- **National Water Resources Master Plan (2015–2035)** to consider water resources and mechanisms for increasing access to irrigation, water and improved sanitation.

Table 1: Malawi metrics

Population	
Total	17 373 000
Urban	15.4%
Rural	84.6%
Poverty, HIV, Unemployment	
Below the international poverty line	71.4%
HIV-positive	5.8%
Unemployment	6.6%
Human Development Index	0.445
Electricity	
Production kWh	1.42bn
Consumption kWh	1.321bn
Airports and Ports	
Airports	32
Kilometres of Services	
Roads	15 492
- Paved	4 074
- Unpaved	11 378
Rail	767
Waterways	700
Africa Infrastructure Development Index	21.02
Access to Services	
Access to safe drinking water	87%
- Urban	98%
- Rural	85%
Access to improved sanitation	55%
- Urban	49%
- Rural	56%
Access to electricity	9%
- Urban	32%
- Rural	4%
Telephones	11 234
Mobile phones	7 178 384
Internet users	10%

- **Malawi National Transport Master Plan (NTMP) (2017–2037)** which seeks to reduce transport costs and improve efficiency and safety across all modes of transport including road, rail, inland water and civil aviation.
- **National Energy Policy (2018)** to guide the development and management of modern, reliable and sufficient energy for all.
- **Industrial Development Programme** aimed at supporting existing and promoting potential manufacturing industries to expand value chains; the focus areas are the sugar, agro-processing, construction, pharmaceutical, cotton, forestry and leather Industries.
- **Education Sector Implementation Plan (2013–2018)** to improve learning outcomes at primary level and expand access to secondary education.

ENGINEERING ACTIVITIES

Figure 1 shows the contribution of engineering-related economic activities to the country's GDP. The largest sectors are agriculture and manufacturing. Considering each in turn will give a picture of the activities, trends, challenges, and opportunities for the engineering profession to contribute to Malawi's growth.

AGRICULTURE

The country relies on tea, sugar cane, coffee and tobacco, making up more than 90% of its export revenue. Other crops include cotton, corn, potatoes and sorghum, while cattle and goats are the main livestock. Tobacco and sugar processing are notable secondary industries.

Subsistence farming

Nearly 90% of the farming population engages in subsistence rain-fed production to feed their families and earn a living. They produce a variety of crops, including maize, beans, rice, cassava, tobacco, and groundnuts (including peanuts). These farmers generally continue with their traditional approach of using hand tools and manpower for farming operations.

As many farms are less than a hectare, improving agricultural productivity is essential for improving food security. Given the abundance of dams, rivers and streams, irrigation offers the potential to move to year-round cropping, producing higher yields from a single plot, and allowing farmers to plant alternative cash or food crops. Improving soil-management techniques and practising conservation agriculture also contributes to productivity gains, which will allow farmers to transition to more diversified, commercial farming.

While some irrigation schemes involve the construction of channels from dams, others use solar-driven or treadle pumps to pump water from rivers, streams, wells and boreholes as required. In 2015 there were still some 23 002 community schemes, out of 39 639 relying solely on rain and the use of watering cans.

To benefit from increased production, post-harvest care needs to be expanded including drying, packing, refrigeration, warehousing and transport to markets. There are several cooperatives in place which purchase excess crops or cash crops for market, with whom communities need to engage. Communities also need to learn to market directly to local supermarkets and agro-processing companies.

Commercial farming

Out of the 400 000 ha of land suitable for irrigation, only 104 000 ha were under irrigation in 2014. The areas shown in Table 2 illustrate the potential to expand irrigation. Considering the scope for expansion, the 2010 Greenbelt Initiative (GBI) was

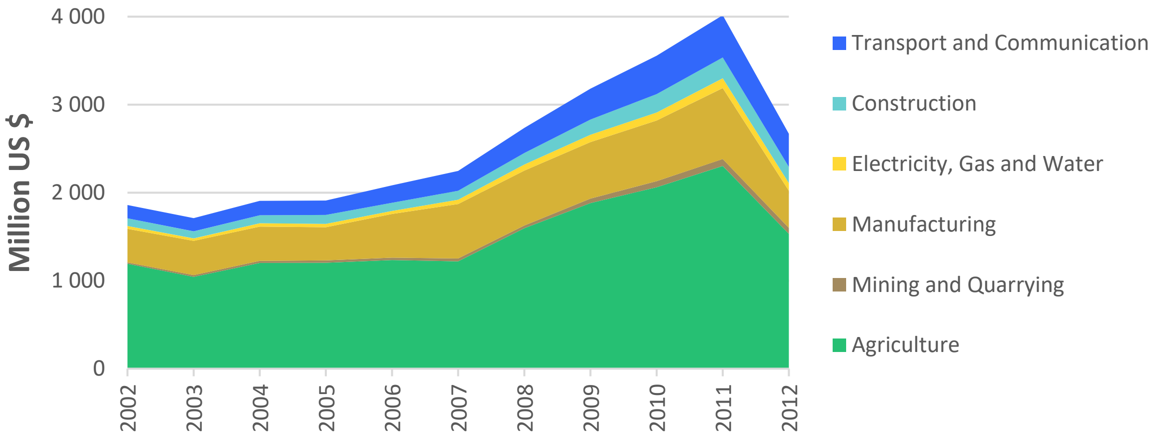


Figure 1: GPD per engineering-related economic activity (49% of the GDP)

conceptualised to revolutionise commercial farming and contribute to economic growth. The rationale of the GBI is to ensure that commercial farmers have access to large tracts of land at the highest possible economies of scales for optimum output. Land was to be identified and farmers linked to banking institutions for inputs such as machinery, fertilisers, seeds, pesticides, labour and cash. Relocation of villages was to be considered where necessary. The GBI has six components:

- Irrigation development and rehabilitation
- Improving access to credit
- Natural resources management
- Research based technology development
- Capacity building, infrastructure and market development
- Dissemination and utilisation of new technologies.

Two possible scenarios were considered in the National Water Resources Master Plan for ramping up irrigation – this was at a rate of 2 500 ha/year or 5 000 ha/year to 2035. The master plan is divided into three terms, namely short-term until 2020, mid-term until 2025, and long-term until 2035.

Several projects are underway, including the Shire River Basin management and irrigation projects, and the Songwe River Basin development programme for implementation in 2020, which will extend the area under irrigation.

Given the importance of irrigation, the Lilongwe University of Agriculture and Natural Resources (LUANAR) has developed an Irrigation Engineering qualification, concentrating more on irrigation approaches and water management and less on mechanisation than in traditional agricultural engineering degrees.

Forestry

Large man-made pine forests are located in the Viphya Mountains, around Mulanje and Zomba. These were established over a long period when it became apparent that indigenous forests would not sustain local and export needs. Maintenance of these protected areas secures major rivers, which support the activities of water boards, irrigation schemes and hydroelectric power generation. Major forests are experiencing pressure due to farming encroachment and illegal exploitation of forest products for timber and firewood.

Fisheries

Lake Malawi has a total surface area of 29 500 km² and is the main source of fish. The lake is said to be the most species-rich lake in the world with up to 1 000 species (mainly Cichlidae species). Peak production of Chambo was 17 400 MT in 1984, but there are several signs of overexploitation, particularly the reduction in the average size of species. Fishing activities are generally limited to small-scale traditional and artisanal operations. However, a semi-industrial trawler fleet also operates in the southern part of Lake Malawi.

MINING AND QUARRYING

Malawi has abundant natural resources, including limestone, and unexploited deposits of uranium, coal and bauxite among others. The majority of the country’s mining and mineral processing operations are privately owned, including the Mchenga Coal Mine, the Kayelekera Uranium Mine, the Nyala Ruby and Sapphire Mine, as well as limestone quarries and cement plants.

The country’s mining exports are mainly uranium, bentonite and gemstones. In 2010, Malawi produced 1% of the world’s uranium but production ceased at the Kayelekera Uranium Mine in 2015 due to the continued depressed price for uranium oxide, which had been negatively impacted since the nuclear reactor damage caused by the Fukushima earthquake and tsunami in March 2011, and the unsustainable cash demand to maintain the loss-making operations. Resumption of mining operations is only likely when

Table 2: Potential irrigation areas (Dept of Irrigation report, 2014/2015)

IRRIGATION SERVICE AREA	AREA (HA)			AREA UNDER IRRIGATION (HA)			
	Total	Arable	Irrigation Potential	Total	Estate	Small Holder	Percentage (%)
Shire V	684 000	313 215	56 876	32 125	26 031	4 172	53%
Blantyre	1 023 900	604 101	39 482	9 782	2 588	8 343	28%
Machinga	1 340 000	550 000	84 517	7 879	1 953	6 257	10%
Lilongwe	1 042 457	600 000	40 340	27 504	12 826	13 557	65%
Salima	656 410	357 713	38 447	10 660	8 692	1 564	27%
Kasungu	1 584 550	966 100	56 738	6 361	183	7 300	13%
Mzuzu	476 900	228 483	69 821	7 897	217	7 822	12%
Karonga	862 700	374 500	21 641	2 416	9	3 129	14%
TOTAL	**7 670 917**	**3 994 112**	**407 862**	**104 623**	**52 499**	**52 144**	**26% (Av.)**

the uranium price reaches US$70-US$75 a pound. At the end of 2017, the price was just under US$25 a pound.

Due to the limited prospects of minerals and/or the remoteness of the mining areas, mining activities are limited to the extraction of coal from the Livingstonia and Rumphi mines in the northern region. However, several of these mines have closed in recent years due to the uncontrolled influx of coal imports from Mozambique's Moatize coalfield. The Mchenga Coal Mine is still operational, but investment in a new mine is required as the reserves are almost depleted.

The tonnage extracted from various quarries was 13 times the tonnage of coal extracted in 2015 and is important for the construction sector. One of the prerogatives of the government is to raise the GDP contribution of the mining sector from 0.9% in the 2014/15 financial year to 20% by 2020. To that end, a programme called the Geological Mapping and Mineral Assessment Project was launched. The programme covers six areas that include geological mapping, mineral resource-potential mapping, natural risks geo-hazard mapping, support for small scale mining, procurement of laboratory and field equipment, construction of a documentation centre at the Geological Survey Department, and capacity building. By mid-2017, exploration had identified sixteen coal seams of varying thicknesses which offered potential.

Several companies are prospecting for graphite, other specialty metals and rare earths and a proposal is being considered for mining heavy mineral sands. This operation will include the development of a concentrator, separation plant and smelters.

MANUFACTURING

There are some 2 065 manufacturing companies in Malawi, employing 83 210 people. Two-thirds are micro-businesses with only 18% employing 20 people or more. The main industries are in agro-processing, including food processing, ginning and the production of sawmill products, fertilisers, furniture and cigarettes. The production of chemicals, rubber, plastics, metal products, machinery and equipment make up the balance.

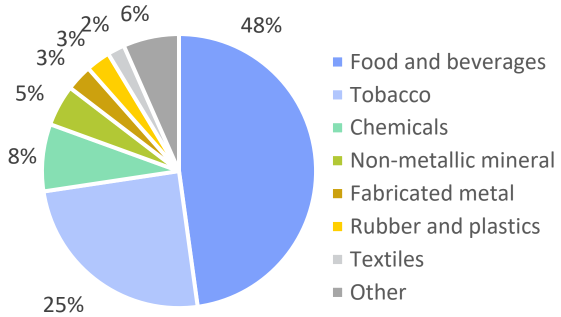


Figure 2: Distribution of manufacturing value add
(National Statistical Office 2016)

Manufacturing companies complain that:

- The cost of transport is high as most inputs come from outside of Africa and must be shipped to the nearest ports in either South Africa or Mozambique before travelling over land to Malawi. Most overland transport is carried by trucks which often go back to ports empty. The rail network is not extensively used, as it needs rehabilitation and the transit times are too long.
- The supply of electricity and water is erratic.
- There is a lack of technical skills able to conceptualise, build and expand businesses.

Food, beverages and tobacco products

Sugar processing, tea, coffee and juice production are notable secondary industries. Interestingly, unlike in other countries in the region, production of many of the final products takes place on the farms, so it is not unusual to find a range of engineers employed on the various sugar and tobacco estates. Maize, dairy, confectionery and various food products are also manufactured locally.

Figure 3: Nchalo Sugar Factory
(Courtesy: Illovo Sugar (Malawi) plc)

Fish processing also takes place, but it is generally very elementary quayside processing.

Carlsberg Malawi is the major producer of beverages in Malawi, producing Carlsberg, Coca-Cola, Fanta, Sprite and the iconic Malawi Gin. The entire process of milling, mashing, lautering and boiling requires engineering skills to manage the process, schedule maintenance and ensure that the operating environment remains under controlled conditions. Carlsberg advise that there is a need for good chemical engineers and operators who are aligned to their methods.

There are many tobacco farms several of which employ engineers to manage the cigarette packing and filter making machines for monoacetate and special filters. The tobacco is either dried, packed and baled for export, or follows the whole process of being moistened, blended, flavoured, dried, rolled, glued, packed and shipped as various brands of cigarettes and cigars.

Textiles, clothing and leather

Cotton has traditionally been an important smallholder cash crop in Malawi. Over the years, production has reduced as has the quality, according to the industry. This is attributed to the mixing of different grades, limited grading by farmers and the general decline of extension services and the resultant decline in cotton husbandry, including pest management.

The number of textile mills has reduced, and fabric for Cut, Make, Trim (CMT) garment firms is imported. As such, the requirement for engineering capacity in the textile sector has reduced over the years.

In terms of leather, goods are generally handmade, and there is no tannery operating at present.

Timber, pulp, paper and packaging

The primary wood-processing industry in Malawi is saw milling, with some production of furniture and building materials including plywood, block boards, shuttering, hardwood, shelving, laminated beams and matches.

Plastics, chemicals and other non-metallic mineral products

The plastics industry produces pipes, polystyrene, films, household goods, furniture, packaging and many other products. Some 1 300 tons of latex rubber is produced per year and is used locally for tyre re-treading, paint and mattress manufacturing. The remainder is exported but offers opportunity to increase local production of shoes, bags, mats and motor vehicle products.

In terms of chemicals, production is minimal, with most chemicals including those for fertilisers, pesticides, textiles, sugar processing, paint formulation, pharmaceuticals and soap making, being imported. There are currently no facilities in Malawi for recycling or recovery of chemicals and related waste which are usually discharged into the sewerage system or rivers.

The production of cement is on the increase which will greatly reduce cement imports.

Pharmaceuticals

Malawi has four pharmaceutical companies that manufacture a limited range of drugs. Although this study is looking at engineering capacity, mention must be made of the fact that there are currently only about 200 pharmacists in the country, a substantial increase from 60 reported in 2005 before the school of pharmacy was opened, but no enough students are following this career and funding for bursaries is needed.

Metal industries, machinery and equipment

A range of metal products are made locally, including cables, nuts, bolts, pipes, fencing, window and door frames, reinforcing and burglar bars, furniture, canopies, trailers, truck bodies, water tanks and sheeting.

As most machinery and equipment is imported, a network of engineers is employed in the supply, rather than the manufacturing space, to assist clients with selecting and specifying the products required, installation and ongoing maintenance.

ELECTRICITY, GAS AND WATER

Electricity

Only 9% of the population had access to electricity, as shown in Figure 4, made up of 32% of the urban population, and a low 4% of the rural population in 2013.

Provision of sufficient, reliable and clean energy is recognised as a critical challenge, and energy is a focus area in both the Growth and Development Strategy and the Economic Recovery Plan (2012). A target of 30% has been set for 2025 and 50% by 2030. The Rural Electrification Act of 2014 aims at ensuring that the majority of peri-urban and rural communities have access to efficient, sustainable and affordable energy for their social and economic development.

The Electricity Supply Corporation (ESCOM) is the sole supplier of electricity. It is divided in to business units: Generation Business Units (GBU), Transmission Business Units (TBU) and Distribution Business Units (DBU).

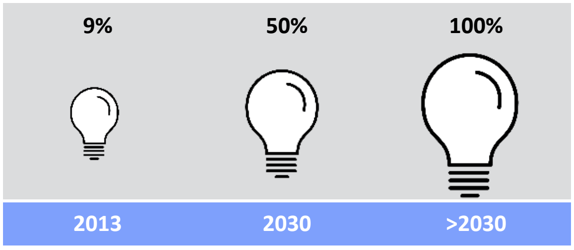


Figure 4: Target dates for access to electricity

Nearly 95% of Malawi's electricity supply is provided by hydropower from the Shire River and a mini hydro plant on the Wovwe River. Total installed capacity is 285.82 MW. Some thermal power plants serve as stand-by, including a 15 MW gas turbine plant in Blantyre and a 1.1 MW diesel power plant in Mzuzu. Likoma District has two separate isolated systems with a total installed thermal power capacity of 1.05 MW.

The demand for electricity far exceeds the installed capacity and new generation capacity is urgently needed. Plans are in place to build a 300 MW coal power station at Kammwanba, the first phase of which should be operating by 2019. Sources over and above hydropower are important, as hydro capacity reduces in years of low rainfall when dam levels drop. Table 3 indicates the diversification of power sources planned.

A 300 MW hydropower plant on the Shire River is planned for completion by 2021. The development of a 400 kV transmission backbone will connect Malawi with the Southern Africa Power Pool (SAPP), allowing the country to access electricity from neighbouring producers during down times. Connection with Mozambique will be operating by 2021. Interconnections with Zambia and Tanzania will also be developed.

The Sustainable Energy for All (SE4All) Action Agenda and Investment Prospectus includes harnessing the private sector and social enterprise to connect remote communities using mini-grids based on renewable energy technologies. The first such project was a US$55 million hydroelectric plant, Kapichira II, opened on the Shire River in 2014, which was handled as a turnkey project contracted to the China Gezhouba (Group) Corporation.

The SE4All intentions are, among others, to:

- Scale up and strengthen Malawi's first mini-grid company operated as a social enterprise
- Build capacity on mini-grids and rural electrification at subnational and national levels
- Recommend ways to mainstream mini-grids into national rural electrification financing platforms and energy regulatory frameworks.

A culture of paying for energy needs to be developed, as many early solar systems, which were fully funded for communities, ceased to operate once batteries needed replacing. Funds for spares and maintenance need to be collected on an ongoing basis.

Ramping up from 9% to 100% connected in a short space of time is going to require a significant increase in engineering skills for planning, project management, and operations and maintenance of the networks. Substantial training programmes within ESCOM and the subcontractor network will be necessary to develop and sustain the expanded infrastructure.

Table 3: Changes in energy sources planned

ENERGY SOURCE	2015	2025	2035
Liquid Fuels and Biofuels	9.9%	13.0%	14.8%
LPG, Biogas and Natural Gas	0.1%	3.7%	9.0%
Electricity from Renewable Sources	6.9%	16.0%	28.8%
Electricity from Non-Renewable Sources	0.3%	5.7%	8.0%
Coal	2.3%	4.1%	4.9%
Electricity from Nuclear Energy	-	-	1.0%
Biomass	80.5%	57.5%	33.5%
TOTAL	**100%**	**100%**	**100%**

Oil and gas

No reserves of oil or gas have been discovered, hence supplies are imported via Tanzania and Mozambique. Locally produced ethanol is added to petrol, making up 10-25% of the fuel. There are 17 storage depots from which major suppliers distribute fuel and oils.

Based on significant findings of oil and gas in surrounding countries, Malawi is exploring prospects for its domestic oil and gas industry in the hope of changing the country's economic landscape, despite the economics of energy, particularly the cost of developing fields isolated from markets.

Water and sanitation

In 2015, 87% of the population had access to safe drinking water, made up of 98% of the urban population, and 85% of the rural population.

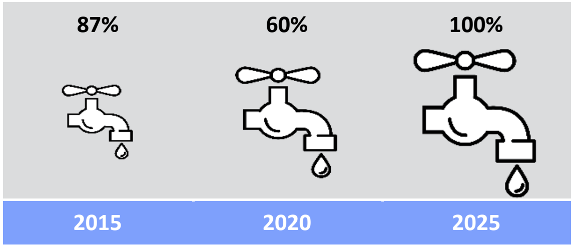


Figure 5: Target dates for access to safe drinking water

Only 55% of the population had access to improved sanitation facilities, made up of 49% of the urban population, and 56% of the rural population. Although 2030 has been set as the target date for universal access to improved sanitation, WASHwatch the international advocacy hub that monitors the delivery of safe water, sanitation and hygiene facilities suggests that at the current rate of progress the target will only be reached many years later.

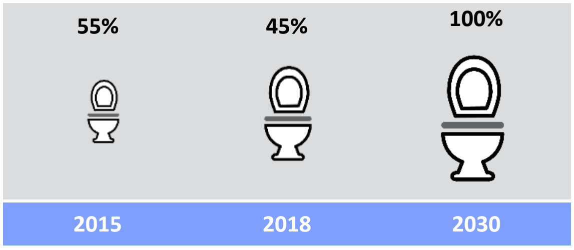


Figure 6: Target dates for access to improved sanitation

The Ministry of Irrigation and Water is responsible for addressing water and sanitation and is composed of several departments, including:

- **Water Resources** whose duty it is to develop and manage ground and surface water resources, and control water quality and pollution.
- **Water Supply and Sanitation** whose duty it is to provide safe water supply services to rural communities in 28 districts and supervise the delivery of water supply and sanitation to town and urban centres by the Water Boards. Water supply activities devolved to the district level are:
    - Operation and maintenance of borehole and hand pump facilities and rehabilitation of the rural piped water supply system. There was a total of 68 625 rural water points in 2010 as shown in Table 4, a large percentage of which were non-functional. Discussions in 2017 suggested that there were some 55 000 boreholes, 40% of which were non-functional.
    - Assurance of availability of spare parts for water supply facilities.
    - Sanitation services, including waste removal and disposal.

Table 4: Status of rural water sources

TYPE OF WATER POINT	NUMBER	NON-FUNCTIONAL
Tap	21 347	31%
Borehole	38 130	19%
Shallow well	8 259	33%
Protected spring	529	33%

- **Irrigation** whose duty it is to promote socio-economic development through irrigated agriculture. Their activities were discussed under *Agriculture.*
- **Sanitation and Hygiene** who ensure holistic planning, designing and development of sanitation programmes.
- **The Northern Region Water Board** which is responsible for water supply in the town of Mzuzu. The City Council lacks machinery, equipment and technical capacity to develop a water and sanitation system able to service all areas of the city.
- **The Lilongwe Water Board** which abstracts its raw water from Lilongwe River. There are two dams constructed along the river; Kamuzu Dam I and Kamuzu Dam II. Siltation and pipe leakages cause water losses of up to 35% of the water produced. The Board has two main treatment plants and serves around 75% of the population.
- **The Blantyre Water Board** which supplies potable water for commercial, industrial, institutional and domestic use for Blantyre. About 46% of slum dwellers access water through kiosks, 11% have piped water, 13% walk long distances to access water, and the rest acquire water from other sources. About 80% of formal settlements have access to piped water.
- **The Central Region Water Board** which is responsible for water services to all towns and commercial centres in the Central Region of Malawi, apart from Lilongwe City.
- **The Southern Region Water Board** which is responsible for water services to Zomba and all towns and commercial centres in the Southern Region.

There is a need to increase water supply in all regions. In Lilongwe, there are plans to raise Kamuzu Dam I, increase the number of boreholes and develop the

Diamphwe Dam. Consideration is also being given to pumping water to the city from Lake Malawi. New water sources from the Shire River are being considered for Blantyre, while building of the Lambilambi and Lichelemu Dams is being considered for Mzuzu and the raising of the Mulunguzi Dam for Zomba.

Not only are the water boards challenged with inadequate water sources, but they suffer from high losses as a result of bursting and leaking of pipes, broken, insufficient or incorrectly calibrated water meters, illegal connections and flushing necessary to remove mud from the pipelines.

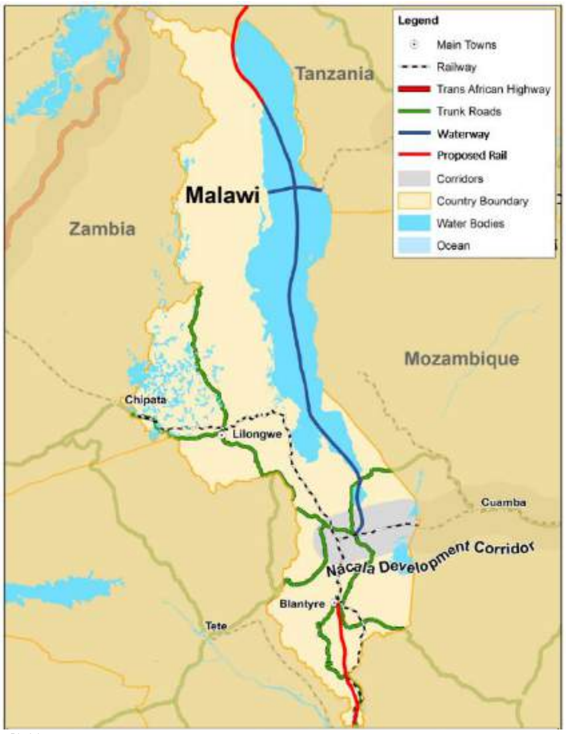
Much effort will be directed at network refurbishments and rehabilitation of works. The challenges in terms of upgrades and maintenance include lack of stock of materials and transport, shortage of personnel, non-payment, low tariffs and limited budgets. To address the water needs an updated National Water Resources Master Plan has been developed, which was launched in 2017. Targets were set for 2035, with middle-term targets to be achieved by 2025 and short-term targets by 2020.

Sewage treatment in cities and providing sanitation services to rural communities is the responsibility of local government. The 2008 census showed that some 82% used traditional pit latrines, 11.7% had no facilities while only 6.3% had access to flush toilets, ventilated improved pit latrines and other improved systems. Poor sanitation practices and improper storage of drinking water lead to water-borne illnesses, notably diarrhoea and cholera.

A serious issue regarding the delivery of water services at both central and regional level is the number of vacant posts. Shortages of engineers and hydrologists limit the ability to strategise, plan, develop, operate and maintain existing and extended facilities. Poor remuneration in the public sector was cited as a major challenge to attracting high calibre professional staff. The vacancy rate was quoted as 66% in the 2013/2014 financial year. In 2017 the water resources, supply and services departments, including the 28 districts, employed a total of only 23 engineers.

TRANSPORT AND COMMUNICATION

Malawi's transport infrastructure falls under the Ministry of Transport and Public Works (MTPW), while communications falls under the Ministry of Information and Communications Technology (MICT).



Disclaimer:
Aurecon gives no warranty of any kind, expressed or implied, with regard to the map or data whether for its reliability, accuracy or completeness and shall not be held liable in any event for any loss or damage in connection with or arising out of the use of this data or map. The Client accepts all inherent limitations of the maps and data, including the fact that the maps and data are dynamic and in a constant state of maintenance, correction and revision. The data and map remain the sole property of the CLIENT and may be used for purposes of this Project with the prior written approval from the CLIENT. aurecon

Figure 7: Transport corridors

Malawi's road and rail networks, and waterway management are inadequate both in their quality and extent, a problem made more serious by the country's reliance on land transport to compensate for its lack of sea access. The need for major investment in upgrades and expansion of the network is outlined in the NTMP from 2017 to 2037. The objectives will be to reduce transport costs, move freight from road to rail and waterways, and to enhance the connectivity of rural areas to support the growth of the agricultural sector. The total funds required for the period will be approximately US$9 billion.

Communication systems are still underdeveloped and need significant expansion.

Roads

The road system has been expanded by 44% since independence in 1964. However, in the same period Malawi's population has doubled. Of its 15 492 km of road, only 4 074 km, i.e. 26%, is paved. The poor condition of the roads has contributed to Malawi recording high road accident rates in world terms, despite its very low car-to-person ratio of 2 per 1 000.

The Roads Authority is responsible for the construction, rehabilitation and maintenance of main, secondary and tertiary roads, while district and urban roads are the responsibility of district and town councils respectively. The Roads Department within the ministry develops and reviews policies, laws, standards and practices for road construction and maintenance.

Nationally, plans are afoot to develop the Nacala Road Corridor which will link the Indian Ocean Port of Nacala in Mozambique to Malawi, and on through Chiponde in Malawi to Zambia and beyond. Upgrades from gravel to surfaced roads, and in some cases widening and expansion, are planned for several major lengths of road, as shown in Table 5. Other planned upgrades include the Chilomoni Ring Road, Living Waters to Zion, the Lirangwe-Chingale-Machinga Road, the Zomba-Jali-Phalombe-Chitakale Road and several municipal roads in Lilongwe, Blantyre, Zomba and Mzuzu. These upgrades will ease the movement of people to main centres and enhance their opportunities for economic activities.

There are also plans to implement the Rural Roads Improvement Programme funded by the European Union (EU). The objective is to contribute to poverty reduction through sustainable agricultural and rural development. This will be achieved by rehabilitating approximately 1 200 km of district rural roads, which will offer smallholder farmers improved access to markets and social services.

Rail

Until 2015, Malawi had only 767 km of track, all of which was narrow gauge. The north-south line travels from Mchinji on the Zambian border to Salima, before going south through Nkaya, Lilongwe and Blantyre to Makhanga on the Mozambique border. The west-east line commences at the Nkaya junction and travels to Nayuchi on the Mozambique border and then on to the deep-water Port of Nacala. A new 136 km line completed in 2015 from Cambulatsissi through Chapananga to Nkaya was constructed to link the Moatize coal mine to the Ncala corridor.

Malawi Railways was managed by the government until privatisation in 1999 when it was sold to the Central East African Railways (CEAR) consortium. Although the rolling stock and service were taken over under the concession, responsibility for the rail network was not considered. When Malawi Railways ceased to exist, the lines were neglected and fell into disrepair, with the condition being exacerbated by Mozambique's civil war, and more recently by extreme weather conditions.

The Limbe-Makhanga line has not been operating since 2015 due to long lengths of rail and bridges being washed away. The recent development of the Nacala rail line, which traverses Malawi, has once again connected Malawi with Mozambique's ports. The Limbe-Makhanga rehabilitation is expected to be complete by 2019.

In the 2014-2019 manifesto, strong emphasis was placed on rehabilitating and expanding the network and the master plan outlines the need to link strategic areas such as ports, industrial zones and local and regional markets in the next ten years. Further upgrades or developments are planned as follows:

- Build an inland port at Liwonde
- Construct a rail line linking TAZARA to Chitipa, Karonga and then Chilumba
- Revive and develop the Mtwara Corridor to gain access to Tanzania Ports
- Rehabilitate the Liwonde-Chipoka-Lilongwe-Mchinji rail line.

In 2010 it was realised that a dedicated railways department within the government was required, and a department was set up under the Ministry of Transport. There is a need to rebuild the engineering capacity which was once in place in the government for planning, scoping and overseeing the development and maintenance of the infrastructure, equipment and operation of the lines. Training for the range of rail practitioners needs to be reinstated. Attracting suitable staff is proving to be a problem due to the low salaries paid by the government.

Airports

Malawi has two international airports, at Lilongwe and Blantyre. Upgrades to the Kamuzu International Airport (KIA) in Lilongwe are planned to enhance the facilities and install new equipment, such as the aircraft surveillance system.

Waterways and ports

Malawi has 700 km of waterways on Lake Malawi and along the Shire River. Reportedly, ships operating on Lake Malawi are old, rarely keep to schedule and carry limited amounts of cargo. Cargo-handling facilities at most lake ports are very limited and present many logistical challenges.

As Malawi is landlocked and relies on seaports in neighbouring countries to handle imports and exports, it is looking at alternative means of moving goods. An option would be to develop a waterway connection between the Malawi town of Nsanje and the Indian Ocean by way of the Shire and Zambezi Rivers. It is thought that this route would reduce import and export transport costs by up to 60%.

However, this option will be very costly and vessel sizes may be limited by draft in some stretches, limiting the viability of the solution. An alternative would be to export through the Mozambique port of Quelimane, which is a shorter distance than to Nacala, but would require the development of a road between Quelimane and the border town of Muloza.

Communications

The telecommunications sector is growing fast but is still underdeveloped. Telephone penetration rates are the lowest in the SADC region. Mobile telephones are more common than fixed-line phones, with 7.18 million mobile subscriptions, which translates to a penetration rate of 39.6%, compared with only 11 234 fixed-line subscriptions, which represent less than 0.1% of the population. Only 9.6% of the population had an internet connection.

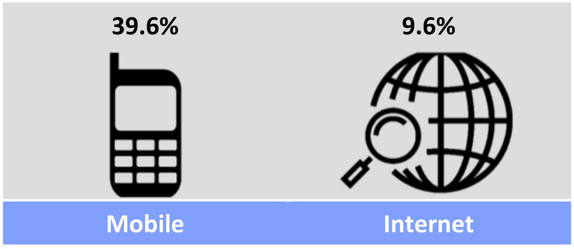


Figure 8: Percentage of population connected to services

The mobile phone service is, at times, unreliable and call rates are considered to be among the highest in the region. The government plans to increase the number of operators from the existing three, namely Airtel, Malawi Telecommunications Limited (MTL) and Telekom Networks Malawi (NM), to increase competition and a drive for efficiency to the sector.

Shortly after MTL was privatised it took the bold step of building a long-distance fibre backbone across the country. The fibre optic cable covers a distance of approximately 2 253 km, linking to Tanzania in the north and Mozambique in the south, via the major cities and towns in Malawi. Additional developments include a national fibre backbone overhaul that will significantly improve communication bandwidth in both urban and rural areas, and improve wireless and wired transmission systems for wider and cheaper access using mobile and fixed broadband mediums. The enhancements are being implemented by the Chinese technology giant, Huawei, in collaboration with ESCOM.

Malawi was connected to the global network initially through Mozambique, and later through Tanzania, providing both improved bandwidth and redundancy, through the Eastern Africa Submarine System (EASSy).

CONSTRUCTION

Construction is important in any country due to its ability to create jobs and develop skills. Malawi however, faces many challenges, including the absence of village colleges to train aspiring labourers and skilled artisans which has limited the opportunities for local labour in the sector. Furthermore, water shortages and power outages need to be addressed, but lack of funding for development is affecting the ability to deliver solutions.

A research project carried out in 2013 identified the 10 key factors which delay road projects. These included the shortage of fuel, insufficient equipment, delay in relocating utilities, shortage of construction materials and shortage of technical personnel, among others.

To address many of these challenges, the National Construction Industry Policy was published in June 2015. The policy outlines government's intent and approaches to be adopted to support infrastructure development. Many major projects are planned as listed in Table 5.

Housing

Significant urbanisation has taken place due to the growing population which cannot be supported on the land. Urbanisation without associated housing, services and job opportunities gives rise to squatters, violence and environmental degradation among others.

The Ministry of Local Government and Rural Development is currently upgrading living conditions by servicing urban unplanned areas of traditional housing with access to clean water, drainage, roads and by processing land ownership certificates.

The Malawi/German co-funded Secondary Centres Development Programme (SCDP) is making progress at containing urban poverty caused by rapid urbanisation. The SCDP is working on transforming urban centres into people friendly centres of national growth by providing economic development opportunities. The SCDP has so far serviced eight urban centres with modern facilities.

The development of rural growth centres is contributing to the improved socio-economic well-being allowing communities to develop improved housing. Infrastructure in growth centres includes school blocks, tele-centres, modern markets, bus stations and processing factories.

Table 5: Major projects identified, or being planned or under construction

PROJECT		VALUE US$	START YEAR	END YEAR
Energy	Expansion of Tedzani hydroelectric power station	$50m	2017	2020
	300 MW Kammwanba coal-fired power station	$667m	2018	2022
	350 MW Hydroelectric power station on the Shire River	In the process of selecting a specialist developer		2021
	Interconnector with Mozambique	$120m	2018	2021
	Interconnector with Tanzania	Planning stage		
	Interconnector with Zambia	Planning stage		
Transport	Blantyre Bypass road (100 km)	$123m	2019	2022
	Nacala Road Corridor Development Project Phase 4 and 5	$120m	2016	2021
	Kaphatenga–Nkhotakota–Dwangwa road (160 km)	$136m	Seeking finance	
	Kacheche–Mzuzu–Mzimba turn off and road (140 km)	$112m	Seeking finance	
	Rumphi-Nyika–Chitipa road upgrade (272 km)	$150m	Start 2018 – 20 km phases	
	KIA turn off to Mzimba and Kacheche–Chiweta M01 road rehabilitation and expansion around Lilongwe (234 km)	$187m	2019	2022
	Sena Line railway rehabilitation and upgrade	Seeking finance		
Water	Pipe water from Lake Malawi to Lilongwe	$500 m	Contractual delays	
	Songwe River Basin Development Project: dam, hydroplant and 3000 ha irrigation between Malawi and Tanzania	$565m	2018	2025

A challenge faced in the housing industry has been the use of clay-fired bricks, which require the use of wood-fuel. The target to reduce this biomass consumption to 31% by 2035, has meant that alternative material must be considered. Soil stabilised bricks and cement bricks are being promoted as there is an increase of local cement production.

LOCAL GOVERNMENT

Local government is made up of four cities and three regions, subdivided into 28 districts. The cities are expected to develop and maintain surfaced and gravel roads, wastewater treatment works, street and traffic lights, fire services and municipal amenities, and to handle building control, traffic and waste management. For this a range of engineering skills is required, along with an adequate fleet of vehicles. With huge backlogs, and limited budgets, roads become impassable in the rainy season adding to the load on the engineering staff.

Although the water boards provide water services to the cities, 75% of the Lilongwe population relies on pit latrines rather than water-borne sanitation. It falls to the cities to provide waste-removal services to the wastewater treatment works, but many are not prepared to pay the charge and sludge is disposed of anywhere, mostly in water bodies, which results in a public health risk.

The role of the 28 districts is to manage water resources, and supply water and sanitation to rural communities. There is a dearth of local government engineers. At the end of 2017, Lilongwe employed only one engineer, in a city which is home to just over one million people. There is thus insufficient capacity to deal with road maintenance, and flooding challenges, exacerbated by climate change, and manage wastewater treatment processes, with the associated risk of water-borne diseases, among many other engineering duties. The other municipalities fortunately had more staff but also mentioned the difficulty of attracting and retaining staff due to low salaries and difficult conditions, including lack of transport, systems and software.

These conditions are not conducive to attending to the well-being of some three million city dwellers.

EDUCATION, TRAINING AND PROFESSIONAL DEVELOPMENT

Education and training is a vital part of developing engineering capacity. All elements, from teaching appropriate subjects at schools to continuing professional development, need to be in place to educate and train engineering personnel and ensure that they remain abreast of the latest technology, challenges and emerging solutions.

PRIMARY AND SECONDARY EDUCATION

Education in Malawi stresses academic preparation leading to access to secondary school and universities. However, only about a quarter of Malawi's youth go to high school and substantially fewer to university as can be seen in Figure 9.

Primary education spans eight years and secondary education four years (Form 1 to Form 4).

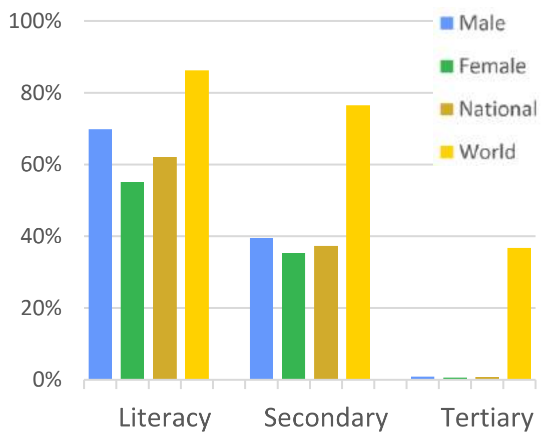


Figure 9: Literacy and enrolment statistics

(UNESCO from 2011 to 2016)

Students must pass the Junior Certificate of Education (JCE) in Form 2, and the Malawi Secondary Certificate of Education (MSCE) in Form 4. Students study English, mathematics, agriculture, physics, biology, geography, history, Bible knowledge, social studies, and ChiChewa.

Secondary education suffers many challenges, including poor student-to-teacher ratios, poor access to books and learning materials, inadequate classroom facilities, and lack of adequately trained teachers.

TERTIARY EDUCATION

To expand higher education and skills development, the government raised funding from the World Bank for five years, from 2014 to 2018, to enhance the production of high-quality professionals. Apart from rehabilitating existing facilities and making student accommodation and subsidies available, the main activities to increase the market relevance of programmes included the need to:

- Provide appropriate equipment, software and internet facilities
- Enhance teaching methods, learning materials, and access to reference material
- Develop, revise and adopt new or updated curricula considering industry needs
- Roll out capacity-building initiatives to address the quality of skills-development trainers.

Understanding the challenges faced by engineering facilities, funding from the Newton Fund, under the first phase of the Royal Academy's Higher Education Partnerships for sub-Saharan Africa (HEPSSA) programme, was made available in 2015. Malawi elected to use the funds to review all engineering curricula, offer academics the opportunity to spend time in industry, and involve professional engineers from industry in higher education teaching and supervision of students. The institutions that offer engineering qualifications in Malawi, are shown in Table 6.

The Polytechnic has been offering engineering qualifications since 1965; these were initially diplomas, but since 1980, degrees have been offered in civil, electrical and mechanical engineering. The MDGS I and II, recognised mining as an important growth sector, and a review carried out by the World Bank revealed that the weak skills base was one of the constraints to developing mineral potential. They listed a shortage of geologists, engineers, metallurgists and mining technicians. Consequently, the Polytechnic has recently introduced mining-related programmes.

A considerable gap was created when Malawi Polytechnic became part of the University of Malawi and technician-level engineering programmes were discontinued. In particular, with increasing public investment in infrastructure, the demand for technical skills in construction occupations is high. Shortages have become apparent at technician level, for site supervisors. After complaints by industry, the Polytechnic is preparing to introduce new technician diplomas in various construction-related occupations. The first cohort is expected to graduate in 2020, hence the annotation of NQ, i.e. None qualified to date, in the Table 6.

Lilongwe University of Agriculture and Natural Resources (LUANAR), previously the Bunda Agricultural College, started offering agricultural engineering qualifications in 1972 and developed an Irrigation Engineering qualification in response to the water-based challenges faced by the sector, which was first offered in 1998. The Malawi Board of Engineers has recognised the qualification and has been registering irrigation engineers since 2015.

Mzuzu University entered the engineering field when it started offering a degree in Renewable Engineering Technology. More recently it added a degree in Water Resource Management and Development to address the water resources challenges in the country.

Malawi's enrolment in skills development institutions and programmes is among the lowest in the world and engineering enrolments are among the lowest in the country. To increase the scientific skills base, the first science and technology university, the Malawi University of Science and Technology (MUST) opened its doors in 2014. MUST offers, among other qualifications, five-year bachelor's degree programmes in biomedical studies, chemical engineering and metallurgical engineering. The first students will graduate in 2019 hence the annotation of NQ i.e. None qualified to date, shown in Table 6.

The addition of chemical engineering is in response to the need to grow the agro-processing and chemical industries; and metallurgical engineering is in response to the shortages in the mining sector, as discussed above. St John the Baptist University commenced offering engineering programmes in 2012 and the first students graduated in 2016.

Civil and electrical engineering programmes have the highest enrolments in engineering, with percentages of 37.8 and 30.2 respectively. Mechanical engineering has only 12.4% of the total engineering enrolments. This is a vital field where efforts should now be made to increase enrolment. The graduation statistics are shown in Figure 10 and the split by gender is shown in Figure 11.

Accreditation

The National Council for Higher Education (NCHE) was established by Act of Parliament No. 15 of 2011 to promote, coordinate and accredit qualifications provided by Higher Education Institutions (HEIs). However, the Engineering Act requires the Board of Engineers (BoE) to accredit qualifications, hence, in the case of engineering qualifications, this responsibility should be devolved to the BoE. Since the BoE has not been officially constituted for periods in recent years, this relationship has not been formalised. Once the new Engineering Bill has been approved by parliament a formal relationship needs to be entered into.

Student mobility

In 2015, there was a total of 963 Malawi nationals studying at South African universities, of which 267 were studying by correspondence, through the University of South Africa.

A total of six engineering students graduated – three completing degrees, one BTech and two National Diplomas. The government of Malawi offers bursaries for engineering students to study outside the country, particularly in fields of study not offered locally.

There are limited post-graduate study opportunities in Malawi, hence those wishing to specialise generally complete post-graduate studies outside the country. Kenya, Tanzania, the UK, Australia, the USA and South Africa appear to be the most popular post-graduate destinations. It must, however, be noted that since the British Council ceased offering funding for post-graduate studies, the numbers pursuing post-graduate studies have reduced, as students cannot afford pay their own fees.

GRADUATE TRAINING

Once the tertiary education phase is complete, it is necessary for graduates to be given structured training in the workplace, under professional supervision and mentorship, to develop to the level of competence required for professional registration, and to be able to take on work independently.

Table 6: Engineering graduations in Malawi in 2014 (unless otherwise stated)

INSTITUTION	QUALIFIC-ATION	Agricultural	Irrigation	Water Resources Management	Chemical	Civil	Electrical & Electronics	Industrial	Mechanical	Mining & Metallurgy	Renewable Energy Technologies
Public institutions											
Lilongwe University of Agriculture and Natural Resources (LUANAR)	BSc	10	38								
Malawi University of Science and Technology (MUST)	BSc(Eng)				NQ					NQ	
Mzuzu University (MZUNI)	BSc(RET)			58							14
University of Malawi Polytechnic, (Zomba)	Diploma					NQ	NQ	NQ	NQ		
	BSc(Eng)					39	19		15	NQ	
Private institutions											
St. John the Baptist University	BEng						9 (2016)				
TOTAL											
Engineer (202)		10	38	58	0	39	28	0	15	0	14

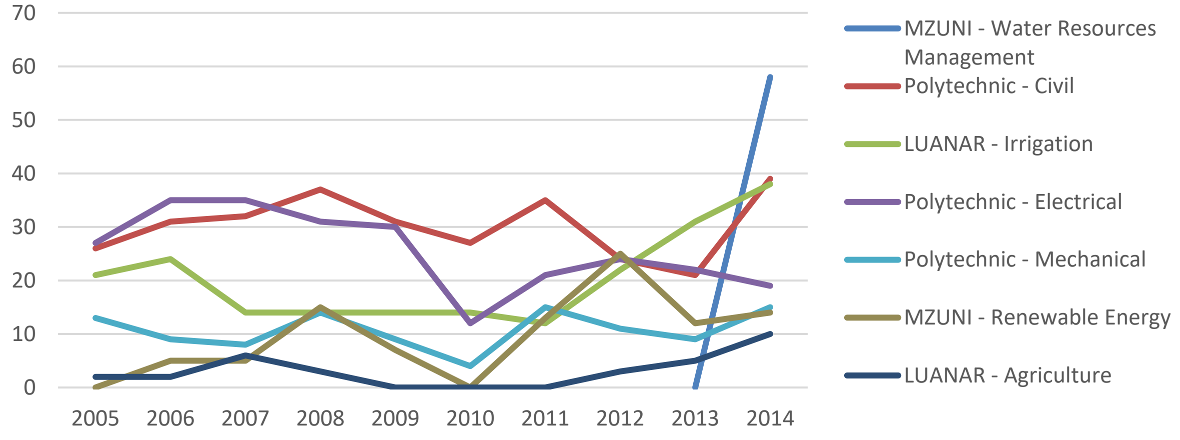


Figure 10: Engineering graduates by institution and discipline

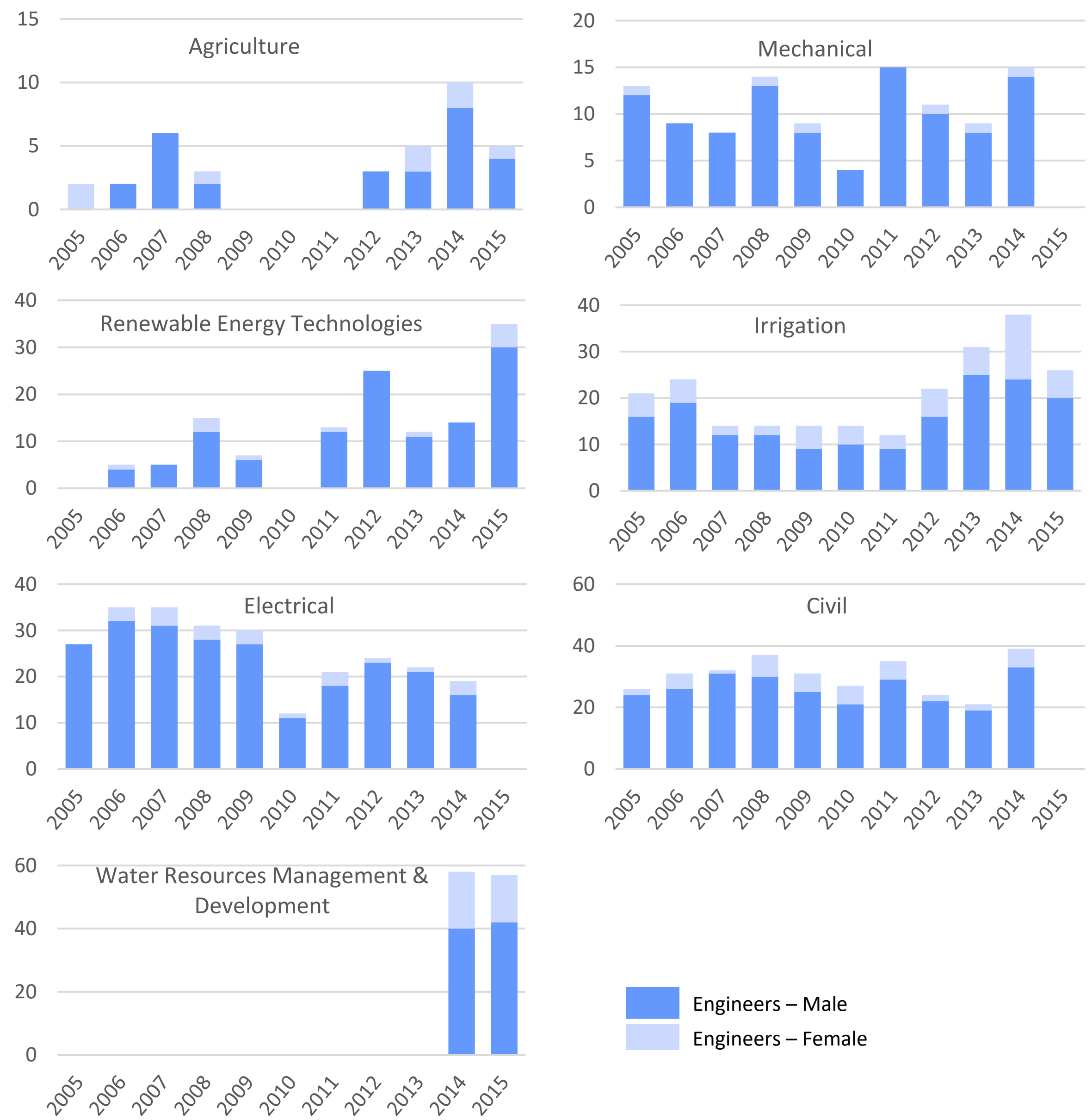


Figure 11: Engineering graduates by discipline and gender

Universities complain that their graduates do not find employment, as industry expects career-ready graduates, and is not prepared to invest in on-the-job training. There is a belief that, as with the teaching and health professions, graduates should have received their practical training as part of the qualification. This is not the case for any built environment, legal or financial professionals.

The need for graduates to be offered structured workplace-based training must be widely publicised, along with training guidelines. The public sector should consider funding national graduate training programmes or offering tax breaks to private sector companies who take on, and train graduates to the level of competence required for professional registration.

Another industry complaint is that graduates lack relevant computer-related skills such as programming, application of engineering software, familiarity with off-the-shelf packages, etc. This has been the case partly because universities focus on formal examinations rather than assessing competencies and skills, and partly because of limited resources. Investment in more IT capacity is essential in higher education engineering departments, along with including more computer training and assignments in the curricula.

PROFESSIONAL REGISTRATION

The Engineers Act of Malawi was first promulgated in December 1972, as Act No. 17 of 1972. The intention was to set up a Board of Engineers (BoE), which would be responsible for registering engineers in the interests of public safety and well-being, and for registering graduates-in-training and persons competent to develop graduates to professional registration. Other important roles were to accredit tertiary education institutions to ensure that the standard of engineering qualifications is upheld and to take disciplinary action against those acting unprofessionally. The BoE was set up in 1974.

An amendment to the Act, the Engineers Amendment Act, No. 5 of 1988, extended the scope of the BoE to register Technician Engineers and Engineering Technicians. Registration statistics since inception are shown in Table 7.

With the change of government in 2000, funding was withdrawn and Board members were not appointed for several years which impacted the functioning of the BoE. Registrations have been processed again since 2013, but the BoE is now expected to be self-funded. Without registration, it is difficult to call engineering practitioners to account when they deliver substandard work.

Table 7: Registration with BoE since inception in 1974

CATEGORY	NUMBER
Engineers	706
Technician Engineers	423
Engineering Technicians	163
Graduate Engineers	1 162
TOTAL	**2 454**

Since 2010 there have been discussions about merging the work of the BoE and the Malawi Institution of Engineers (MIE) and forming a new organisation, the Malawi Engineering Institution (MEI) to cover both voluntary association and registration functions. A private bill has been prepared and submitted to the National Assembly. The new bill includes the requirement for Continuing Professional Development (CPD) and makes provision for the registration of an extended range of engineering practitioners, including craftsman. As of the end of 2018, the bill had been approved by Cabinet but had yet to serve before Parliament.

VOLUNTARY ASSOCIATIONS AND CONTINUING PROFESSIONAL DEVELOPMENT (CPD)

The MIE was formed in 1998 to be the source of information and technological knowledge sharing for engineers and technicians practising in Malawi. The MIE engages with educational institutions, hosts events and offers CPD activities in the interests of its members.

Table 8: Membership of the MIE, 2017

DISCIPLINE	Fellow	Corporate	Associate	Technician	Graduate	Student	Total
Civil	10	40	109	11	81	43	294
Electrical & Systems	2	11	93	69	36	82	293
Mechanical		20	76	20	33	23	172
Irrigation		1	11	1	4	27	44
Energy		1	7		3	98	109
Telecommuni-cation		2	6	13	1	5	27
Chemical		1	2	2	1		6
Aircraft		1	1				2
Marine				2		1	3
Mining				1			1
Industrial						5	5
TOTAL	**12**	**77**	**305**	**119**	**159**	**284**	**956**

Table 9: Estimated number of engineering practitioners by discipline, qualification, gender and age in 2015

DISCIPLINE	Diploma	Degree	Masters	Doctorate	M	F	<35	35-49	>49	Total
Agricultural	125	100	10	5	200	40	120	90	30	240
Chemical	3	2	0	0	5		1	2	2	5
Civil	435	500	50	15	900	100	550	350	100	1000
Electrical	425	400	25	10	800	60	500	260	100	860
Mechanical/Industrial	170	200	25	10	400	5	205	140	60	405
Mining	16	3	1	0	20	0	10	5	5	20
Metallurgy	2	2	1	0	5	0	2	2	1	5
TOTAL	**1176**	**1207**	**112**	**40**	**2330**	**205**	**1388**	**849**	**298**	**2535**

Its outreach is also aimed at the general public and government to make them aware of the importance of engineering for the nation's health and wealth, and to ensure a positive attitude towards engineers and those who aspire to become engineers. The MIE has a range of member categories, as shown in Table 8. The MIE estimates that some 25 to 30% of engineering practitioners belong to the institution.

WOMEN IN ENGINEERING

The Women in Engineering Section was launched at the MIE AGM held in November 2017. Malawian female engineers donned their pink hard hats to celebrate the launch of this Section. Their aim is to encourage women to enter the profession and support practitioners throughout their careers.

The Royal Academy of Engineering has made funding available to the Section for support from the South African *WomEng*, who will assist with the implementation of their programmes, including high school STEM awareness and university employability, entrepreneurship and skills training for female engineers.

Figure 12: Regina Chimwaza demonstrating that she can be a mother and female engineer

THE WORKFORCE

Malawi has one of the highest people-to-engineer ratios on the continent. In 2015, Dr Esther Phiri considered graduation history and estimated that there were some 2 500 engineers and technicians in that year as shown in Table 9. The age and gender distribution in the industry is shown on Figure 13 based on MIE membership.

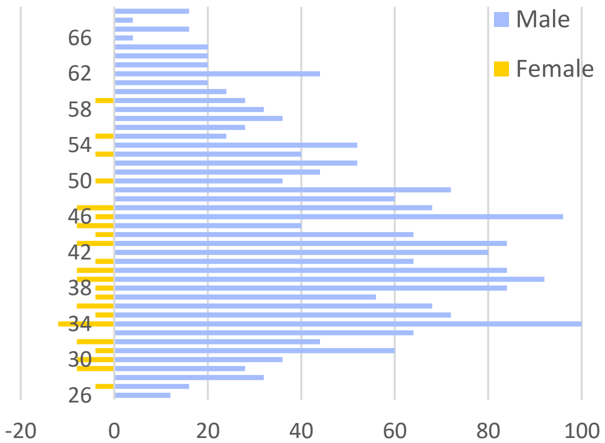


Figure 13: Population breakdown by age and gender based on MIE membership

The older practitioners include foreign nationals, while the young group consists largely of locals. Shortages of engineering skills will continue to be felt until graduates from the new courses have been adequately trained and middle management levels have been groomed into senior strategic positions. Graduate training efforts are therefore of paramount importance to grow tomorrow's engineering practitioners. Assessing the numbers estimated for each sector indicates that the engineering workforce may be as high as 3 200.

THE PRIVATE SECTOR

The main employers in the private sector are consulting, contracting and manufacturing companies, suppliers and quarries. Lower numbers are employed in small entrepreneurial companies, training organisations and other companies where engineering input is required, as well as many NGOs assisting with social structure, rural development and enhancing farming methods.

Consulting

Consulting Engineering firms must be registered with the National Construction Industry Council (NCIC) before they can practise and must employ at least one engineer, who is professionally registered in Malawi. Foreign companies are expected to register with the NCIC and by signing up a single Malawian engineer may deliver their services. As a result, local companies have complained of limited market share. In response, Consulting Joint Venture regulations were put in place requiring at least 51% of work to be carried out by local partners. By the end of 2017, some 39% of work was in the hands of local companies. There are 50 consulting firms registered with the NCIC. It is estimated that together they employ some 300 engineers and technicians.

The Association of Consulting Engineers of Malawi (ACEM) is a voluntary association which brings together companies and firms that provide consulting engineering services in Malawi. Through this association members are able to interact and advance their interests and government institutions and the private sector are able to solicit their views.

Contracting

The shortage of engineering capacity and capital is a challenge to contracting as foreign firms, which have more engineering capacity and capital for machinery and equipment, continue to dominate the construction sector. According to the NCIC, foreign firms in the 22 top firms, hold 84% of the contractor market share, while local firms scramble for the remaining business.

There are over 800 contactors, as shown in Table *10*. It is estimated that some 700 engineering practitioners are employed in contracting.

The NCIC, which was set up through the National Construction Industry Act, No. 19 of 1996, published additional rules in 2014 which aim to help local contractors get a larger share in the construction industry and implement a sustainable level of work, services, skills and technological transfer. The NCIC is responsible for registering contractors, consultants and construction material manufactures/suppliers, both local and foreign before undertaking or completing any construction work in Malawi. They are also tasked with promoting safety in the construction industry, reviewing procedures for awarding contracts, and disciplining persons who breach industry regulations.

Table 10: Contractors in Malawi in October 2017

(NCIC data)

TURNOVER (Ks 000)	Building Construction Works	Civil Engineering Construction Works	Electrical Construction Works	Total
Above 1 000 000	37	34	19	90
Up to 1 000 000	12	8	0	20
Up to 500 000	53	32	2	87
Up to 200 000	106	65	4	175
Below 80 000	200	229	56	485
TOTAL	**408**	**368**	**81**	**857**

The Act or rules need to be extended to call on consultants and contractors to train graduates as part of their contracts, and to provide all calculations, drawings and operating manuals in English. The Act should also prescribe that local consultants must have checked and approved design philosophies and calculations to ensure that local standards and customs are upheld.

Manufacturing

There are some 80 manufacturing and agro-processing companies working with the Malawi Investment and Trade Centre to seek export opportunities for their products. It is estimated that some 200 to 300 engineering practitioners from all disciplines are employed in the sector, the most widely used being mechanical and electrical engineers. The need to optimise processes and improve productivity in many plants has been recognised, hence the introduction of Industrial Engineering at the Polytechnic. The Malawi Confederation of Chambers of Commerce (MCCCI) represent the interests of manufacturers.

Mining

There are about 40 mining and quarrying companies. In 2016, 16 mining companies were attributed with being the major contributors to the mining and quarrying income and output in Malawi. The industry was estimated to employ some 13 000 workers formally at the time. Several thousand more are involved in artisanal mining.

As a large percentage of the industry is involved in quarrying, it is estimated that only 80 to 100 engineers and technicians are involved in the sector at present. Recognising the government's determination to develop the mining industry, the Ministry of Natural Resources, Energy and Mining (MNREM) has engaged with the University of Malawi to review curricula and introduce mining-related courses.

Most companies are members of the Malawi Chamber of Mines, which was established to serve the interests of the mining and exploration companies together and associated industries.

THE PUBLIC SECTOR

Many engineering practitioners are required in the public sector, including in municipalities, to plan new services, issue project tenders and oversee delivery and operate and maintain infrastructure. Table 11 shows the departments that are the main employers of engineering skills. There are several other structures which do not require large numbers, but employ engineers nevertheless, such as the Ministries of Disaster and Relief Management, Health, Sports, Community Development, Research Councils, etc. Considering all the submissions received, it is estimated that the public sector employs some 1 200 engineering practitioners.

Of great concern is the number of vacancies. The Water Boards advised that they had 25% vacancies in 2017, the Ministry of Transport and Public Works had 56% vacancies in technical posts, the Ministry of Irrigation and Water had 62% and the municipalities have few technical staff.

The challenge throughout appears to be the level of remuneration and critical projects not being prioritised and receiving budget. The public sector and particularly local government are challenging places to work due to the shortages of staff, often a lack of transport, limited (if any) software, among other things, making it difficult for engineers to perform. Furthermore, there has been a moratorium on employing staff in the past few years, from which it is going to be difficult to recover.

AGRICULTURE

Since Malawi's economy and population are so heavily dependent on agriculture, there are many agricultural engineers in both the public and private sectors. Engineers in the public sector generally assist small-holders to improve their productivity, while engineers in the private sector are found on commercial farms, and in consulting and contracting, offering their services to both sectors. It is estimated that there are 250 to 300 agricultural engineering practitioners. The Malawi Society of Agricultural Engineers represents their interests.

Table 11: Ministries employing engineering practitioners

MINISTRY/STRUCTURE
Ministry of Agriculture, Irrigation and Water Development (MIAWD) including Water Boards • Blantyre Water Board • Central Region Water Board • Lilongwe Water Board • Northern Region Water Board • Southern Region Water Board
Ministry of Finance, Economic Planning and Development • Road Fund Administration
Ministry of Industry, Trade and Tourism (MITT) • Malawi Bureau of Standards
Ministry of Information and Communications Technology • Malawi Posts Corporation (MPC) • Malawi Telecommunications Limited (MTL) • Malawi Broadcasting Corporation (MBC) • Malawi Communications Regulatory Authority (MACRA)
Ministry of National Defence
Ministry of Natural Resources, Energy and Mining (MNREM) • Electricity Supply Corporation of Malawi (ESCOM) • Department of Energy Affairs • Malawi Energy Regulatory Authority (MERA) • Department of Mines
Ministry of Transport and Public Works (MTPW) • Roads Authority • Roads Department • Building Department • Department of Transport Planning • National Surface Transport Authority (NSTA) • Department of Rail Services • Malawi Railways Limited • Central East Africa Railways (CEAR) • Department of Marine Services • Malawi Ports Company • Department of Civil Aviation (DCA) • Malawi Airport Authority • Railway and Maritime Regulatory Authority of Malawi (RAMRAM)
Ministry of Local Government and Rural Development (LGRD) • Malawi Local Government Association (MALGA) • Municipalities and Districts
Ministry of Lands, Housing and Urban Development (MLHUD) • Malawi Housing Corporation (MHC) • Department of Land • Department of Housing • Department of Urban Development

MIGRATION TRENDS

Analysis of the United Nations Population Division statistics for 2015 shows a net loss of professionals from Malawi. Of those entering the country, 25% were from Zambia and 23% from Zimbabwe. Thirty-eight per cent of professional emigrants moved to Mozambique, 32% to South Africa and a further 17% moved to Zimbabwe.

ENGINEERING NUMBERS AND NEEDS

Combining all the data, it is estimated that there are approximately 3 200 engineering practitioners in Malawi, as shown in Table 12.

Table 12: Estimated numbers of engineering practitioners in the engineering workforce

SECTOR	ESTIMATED NUMBER
Academia and research	140
Agriculture	250
Consulting	300
Contracting	700
Government	1 200
ICT, systems and telecommunications	100
Manufacturers and suppliers	300
Mining	50
Miscellaneous and NGOs	160
TOTAL	**3 200**

In view of the huge number of vacancies in the public sector, it is suggested that Malawi needs 4 000 to 5 000 engineering practitioners. In 2015 there were 200 graduates, but with the introduction of new courses and the two new institutions, it is expected that the number of graduations will reach 320 by 2020, including the technician qualifications.

Figure 14 shows the current workforce, the losses that will occur over the 18-year period to 2035 due to retirement, mobility and mortality, and the growth in engineering capacity if engineering graduations increase at 2% per year over the period.

The blue dotted line shows the growth in skills that would be required at the 2017 GDP growth rate of 4% and the green dotted line shows the growth based on the 2018-2023 GDP projection of 5.2%. A 70% employment elasticity factor has been used to extrapolate the employment demand.*1

The supply exceeds the current workforce demand. However, considering the view that a larger engineering workforce is required of around 4 500 the desired number will be achieved by 2024 if the demand remains static. If the demand increases at the projected growth rate of 5.2% this will move out to 2033. To achieve the increased numbers commitment will be required to start filling posts immediately and investing in graduates to ensure that they develop the competence required to assist with the current workload.

Should large-scale appointments not take place and the 5.2% growth rate continues, the number of graduates will substantially exceed the demand. If Agenda 2063 growth rates can be achieved, the rate of graduation will slightly exceed the demand.

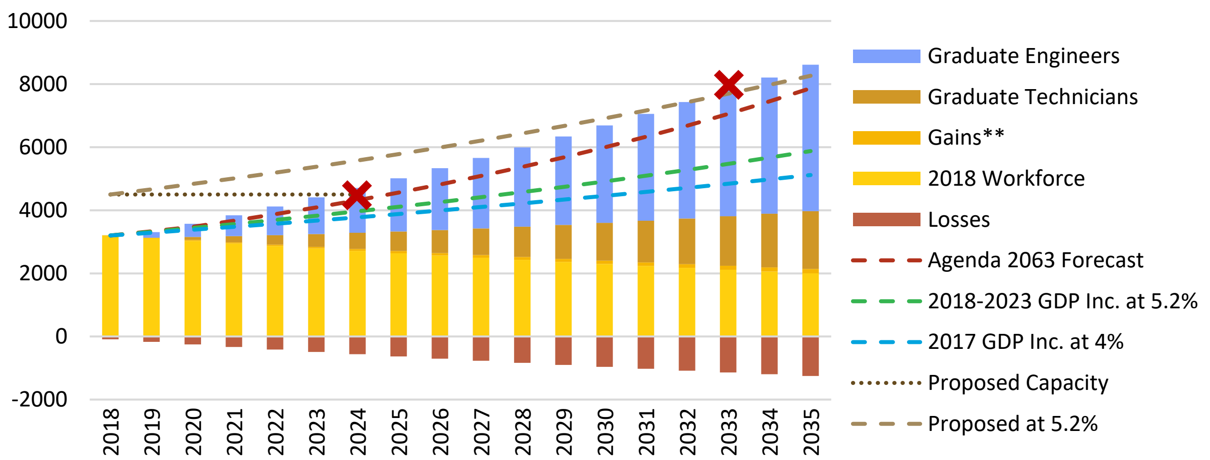


Figure 14: Flow of engineering skills based on a 2% increase in graduation rate per year

***Excludes international engineering practitioners in the country on short-term contracts*

*1 Employment elasticity is a measure of the percentage change in employment associated with a 1% change in economic growth. If the growth is likely to be in agriculture, the percentage could be lower, as growth in that sector is generally to do with productivity gains and not employment, while if the growth is likely to be in high tech manufacturing, the elasticity factor maybe more than 100%.

The increased number graduating can only be absorbed if government reprioritises its budgets and invests in infrastructure development and maintenance, and if the private sector is able to attract investment and expand to achieve the industrialisation targets.

The large number of graduates who will be coming into the system will need to be supervised and coached by a diminishing group of experienced practitioners. It is critical that a national programme for graduate training, development and succession planning is put in place.

Should the country continue business as usual and use only 3 200 engineering practitioners, there will be many unemployed engineering graduates, as can be seen in Figure 14.

The need to increase the number per discipline has already been discussed in the tertiary education section, as part of the rationale for new institutions and new courses. It must be noted, however, that the number of civil and electrical engineers being trained should not be reduced, if Malawi is to reach its goal of delivering safe drinking water, improved sanitation and electricity to the entire population.

KEY RECOMMENDATIONS

To develop a sound pool of engineering professionals, able to contribute to the well-being of Malawi, the following should be considered:

Schooling

- **Primary and secondary education:** Address the weaknesses in primary and secondary education, and increase the number completing secondary education with acceptable results.
- **Career guidance:** Expand career guidance to attract high-calibre entrants into the engineering profession, incorporating programmes to reach female learners, and rural and low-income areas.
- **Bursaries:** Provide bursaries to attract those who excel in mathematics and science to study engineering.

Tertiary education

- **Accreditation:** Develop a rigorous accreditation programme in collaboration with the BoE to ensure the quality of engineering education using the guidelines of the Washington, Sydney and Dublin Accords.
  - Encourage institutions to develop adequate complex engineering problem-solving content and graduate attributes to satisfy the requirements of the Accords.
- **Industry liaison:** Liaise with industry on a regular basis to ensure that curricula, methods, software and equipment are relevant and up to date.
- **Curricula:** Provide funding to research, modernise or develop curricula and material where required.
- **Facilities:** Raise funding to upgrade lecture theatres, libraries and laboratory facilities where required.
- **Resources:** Raise funding for computers, engineering software, access to online reference material, and laboratory equipment, and ensure adequate support to offer technology-relevant training.
- **Attract and retain academics:** Improve conditions of service, support and packages to attract, retain and appoint additional academics.
- **Academic development:** Provide funding for lecturer post-graduate development and facilitate opportunities for academics to gain experience in industry.
- **Enrolments:** Ensure that sufficient mechanical, chemical, mining engineering and metallurgy students are enrolled each year.

Graduate training

- **Develop programmes:** Develop national graduate training programmes to ensure graduates achieve the level of competence required by industry and for professional registration.
- **Private sector incentives:** Offer tax rebates or incentives for private sector companies to develop graduates.
- **Public sector support:** Ensure that public sector structures take on and train graduates and that they are absorbed and developed through the ranks.
- **Institutional support:** Institutionalise graduate training in all organisations by setting KPIs for experienced staff to act as supervisors and mentors.
- **Project support:** Make graduate training a requirement of all public sector projects and ensure that the progress of graduates is monitored, and penalties are imposed for non-compliance.

Registration of engineering professionals

- **Legislation:** Finalise and adopt the new Malawi Engineering Institution (MEI) Bill and fund the development and strengthening of the MEI until it is able to operate as a fully-fledged learned society and registering body.

Continuing development

- **CPD:** Support the participation of engineering practitioners in CPD activities.
- **Validation:** Validate short courses and skills programmes for a specified period only to ensure that training remains up to date and relevant.
- **Post-graduate studies:** Provide post-graduate bursaries to develop specialists.
- **Develop managers and leaders:** Encourage industry to continue investing in graduates after professional registration to grow management and leadership capabilities.

Registration of service providers

- **Legislation:** Expand the National Construction Industry Act to:
  - Ensure that there are requirements for consultants and contractors to train graduates, artisans and other construction-related skills.
  - Ensure that international consultants provide all calculations, drawings, operating manuals and other reference material in English.
  - Ensure that local consultants, along with the client, check that design proposals address local needs and customs and that design calculations comply with national codes and standards.
- **Enforcement:** Enforce the Act to ensure increasing the use of local consultants, contractors, labour, plant and materials and that foreign consultants and contractors partner with local companies.
- **Quality:** Implement quality assurance on all projects and ensure penalties are imposed for poor performance.

The public sector

- **Lift moratorium:** Lift the moratorium on employment of public sector officials.
- **Economic infrastructure:** Invest in the development of economic infrastructure such as electricity, roads, rail, ports and airports, and address the supply of water services.
- **Maintenance:** Invest in maintenance to preserve new infrastructure and prevent further deterioration of existing infrastructure.
- **Tariffs and payment:** Review and increase tariffs where appropriate, enhance domestic revenue collection and demand management to fund development.
- **Technical capacity:** Reprioritise budgets to fill vacant posts and build technical capacity, ensure that salaries are competitive and develop succession plans to make the public sector an employer of choice.
- **Technical decision-makers:** Ensure that engineers are employed in senior decision-making posts.

Industry-wide collaboration

- **Advisory team:** Set up an engineering advisory team, recognised by government, to advise on and endorse infrastructure development proposals, tertiary curricula and graduate training programmes.
- **Collaboration:** Encourage all professional bodies to work together to share knowledge, exchange best practice and ensure coordinated planning of industry support initiatives.

ACKNOWLEDGEMENTS

The detailed picture presented would not have been possible without the support of academics, the MIE, other associations, many government departments, water boards and many passionate engineers. Thank you to Principal Secretary Francis Chinsinga for being available and for making staff available for interviews and providing transport. Thanks go to academics, Drs Lameck Fiwa, Collen Zalengera and Michael Zimba and Profs Theresa Mkandawire and Ignasio Ngoma for contacts and graduation data. Thank you too to David Mzandu and Martin Chizalema of the MIE, Gerald Khonje of the NCIC, John Kumwenda and Geoffrey Mamba of MIAWD and Kelvin Mphonda of MTPW for all the data gathered, master plans and information, and to Washington Chimuzu for input on agricultural engineering. There were many others from both the private and public sectors who went out of their way to offer input – thank you to you all.

SOURCES OF INFORMATION

Data and information were gathered during the MIE Conference in 2017, meetings, interviews and telephone conversations, and via email. SADC reports, many recently launched master plans and strategies as listed under *Plans and Strategies*, and many standard international sets of data as listed in Chapter 5, *Research Approach,* were also consulted. Extensive reference was made to labour and business information published by the National Statistics Office and infrastructure and services data published on the Logistics Capacity Assessment portal. Comprehensive documents focusing on specific issues in Malawi as listed below were additional sources of information.

Kanghulungo, O. 2015. *State of the engineering profession in Malawi*. Malawi Institution of Engineers (MIE) Conference, 18–19 October 2015, Nkopola, Malawi.

Louise Berger International, Inc. 1979. Engineering Manpower Survey of Malawi. Washington, DC: USAID.

MFEPD (Ministry of Finance, Economic Planning and Development). 2017. *Annual Economic Report 2016*. Lilongwe.

Mkandawire, T. 2016. *Inspiring innovation: Engineering outreach with secondary school students in southern Malawi*. Outreach report on a collaboration between the University of Malawi, Virginia Tech, the Malawi Institute of Engineers, and the Electricity Supply Corporation of Malawi.

Mkandawire, T. 2016. *The state of engineering education in Malawi.* PowerPoint presentation made in October 2016.

MAURITIUS

MAURITIUS is an island nation off the south-east coast of the African continent in the south-west Indian Ocean. It is located east of Madagascar.

Mauritius is highly ranked for democracy, its open economy and political freedom, and in 2014, boasted the highest Human Development Index, and the lowest poverty rate in the SADC region. Impressively, almost 100% of the population had access to safe drinking water, improved sanitation facilities and electricity in 2015 and universal access has since been achieved.

Since independence in 1968, Mauritius has developed from a low-income, monocrop economy based on sugar to an upper middle-income diversified economy based on tourism, textiles, sugar and financial services. More recently, information and communication technology, education and training, property development, among others, have emerged as important sectors, attracting substantial investment from both local and foreign investors.

Mauritius has no exploitable natural resources and therefore depends on imported petroleum products to meet most of its energy requirements.

The capital is Port Louis, which is the largest city, the commercial, industrial and administrative centre, and the main port. About 45% of the population live in the Port Louis/Plaine Wilhems conurbation, comprising Beau-Bassin, Rose Hill, Quatre Bornes, Vacoas, Phoenix and Curepipe. There are just over 1 000 squatter families living mainly on the outskirts of cities in un-serviced areas, who are difficult to relocate due to land constraints.

THE ECONOMY

Benefiting from a long history of political stability, a good governance record and an open and flexible regulatory system, Mauritius overtook South Africa in 2014 to become the continent's most competitive economy. Since 2006, the economy has achieved annual growth rates of more than 3%, despite the global slowdown. With a population of only 1.26 million, the island nevertheless welcomes over 1.3 million tourists per year, up from 35 000 in 1970.

Mauritius has managed to diversify its economy successfully by investing in the manufacturing sector. Initially, the focus was placed on the production of textiles and clothing, but the sector now includes the export of jewellery and watch components, among others. Growth has also taken place in the service sectors, but with substantial contributions from other sectors such as ICT (business process outsourcing, call centres and software development); hospitality and property development (commercial malls, luxury villas and international flagship hotels); the seafood and marine industry (aquaculture, fishing, and processing); and the biomedical industry (medical devices, pharmaceutical products and multi-specialty hospitals).

THE CHALLENGE OF BEING A SMALL ISLAND DEVELOPING STATE (SIDS)

Island states have particular challenges when considering long-term development, including small but growing populations, limited resources, remoteness, susceptibility to natural disasters, vulnerability to external shocks, dependence on international trade, and fragile environments.

Classified as a Small Island Developing State (SIDS), Mauritius is densely populated and there is limited

Table 1: Mauritius metrics

Population	
Total	1 265 000
Urban	41%
Rural	59%
Poverty, HIV, Unemployment	
Below international poverty line	0.5%
HIV-positive	<1%
Unemployment	7.90%
Human Development Index	0.777
Electricity	
Production kWh	2.9bn
Consumption kWh	2.73bn
Ports and Airports	
Airports	5
- Paved	2
- Unpaved	3
Ports	28
Kilometres of Services	
Roads	2 428
- Paved	2 379
- Unpaved	49
Africa Infrastructure Development Index	76.79
Access to Services	
Access to safe drinking water	100%
- Urban	100%
- Rural	99%
Access to improved sanitation	100%
- Urban	100%
- Rural	100%
Access to electricity	99%
Telephones	389 500
Mobile phones	1 814 000
Internet users	52%

space for development. The population density was 620 people per square kilometre in 2015, which was the seventeenth highest in the world. Understanding the challenge of limited space and resources at the time of independence, Mauritius introduced a family planning policy that offered incentives for families to have fewer children. This has slowed the rate of population growth to the point where the population is predicted to reduce over the coming years unless the policies are revised.

There is a need to balance demand for land between commerce, agriculture and transportation. The number of vehicles has increased, despite high taxes, and traffic jams are commonplace. A Metro Rail network and Bus Rapid Transit (BRT) system from Port Louis to Curepipe are under construction, and the development of hi-tech, low-footprint industries is being encouraged to increase exports.

PLANS AND STRATEGIES

Mauritius strives to become a high-income economy and has developed innovative plans and policies to take the country forward, many of which will require an increased skills base. The most important strategies are the:

- **Second Economic Miracle and Vision 2030** which aims to jumpstart a phase of high growth, offering incentives for private sector investment, to address unemployment through sustainable development and innovation, focusing on high-tech manufacturing and expanding the services sector, the ocean economy and the Mauritian footprint in Africa.
- **National Development Strategy (NDS) (2003–2023)** which outlines the development objectives and spatial plans to encourage growth, while the **Strategic Plan (2017/2018–2019/2020)** provides short- to medium-term strategic direction and targets to ensure that the development of the growth sectors and enablers remains on track.
- **Long-term Energy Strategy (2009–2025)** which aims to reduce reliance on imported fossil fuels, ensure affordable energy for consumers and democratise energy supply.
- **National Water Policy** which aims to ensure that water resources are developed for economic and social benefits for all, and sets targets of 100% safe and reliable water supplies by 2020 and 75% coverage of sewerage reticulation by 2040.
- **Strategic Plan for the Food Crop, Livestock and Forestry Sectors (2016–2020)** aimed at addressing food security and promoting the development of agri-businesses.
- **National Strategy for Adaptation to and Mitigation of Climate Change (2013–2025)** which aims for the island to be a world model for sustainable development, considering the environment, education and employment opportunities, and includes a target of 35% renewable energy by 2025.
- **Education and Human Resources Strategy Plan (2008–2020)** which aims to transform Mauritius into a highly skilled nation, to foster innovation, generate new knowledge for socio-economic and sustainable development, and transform to a knowledge economy. It seeks to ensure access to learning opportunities for all citizens to achieve personal growth, develop critical thinking skills and adapt to changing environments.

ENGINEERING ACTIVITIES

Figure 1 shows the contribution of engineering-related economic activities to the country's GDP. The largest sector is manufacturing, followed by transport and communication. Considering each in turn will give a picture of the activities, trends, challenges and opportunities for the engineering profession to contribute to the growth of Mauritius.

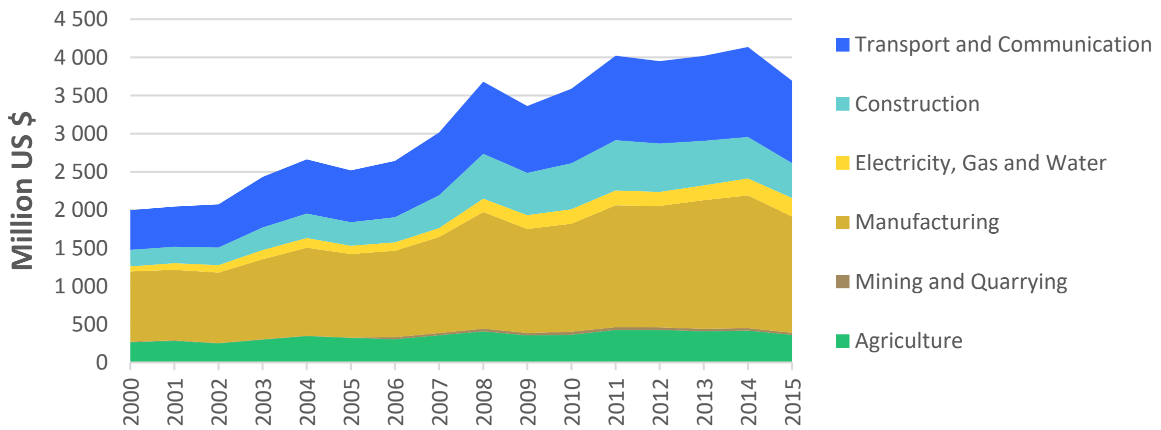


Figure 1: GPD per engineering-related economic activity (36% of the GDP)

AGRICULTURE

Farming

About 40% of the island's surface is used for cultivation, of which roughly 90% is sugarcane, the balance being tea, tobacco and food crops, including vegetables and fruit such as bananas, pineapples, litchis and mangoes. Typically, food crops, fruit and ornamental plants are cultivated by some 8 000 small growers and 375 hydroponic producers, while about 5 000 farmers are active in livestock, and sugar farming is the domain of the corporate sector.

The extent of sugarcane production has led to agriculture being an important contributor to the Mauritian economy. It has, over the years, gone through phases of modernisation and diversification. Today it produces refined white sugar, special sugars, molasses, energy and ethanol.

Although there is a continuing loss of sugarcane fields because of residential and industrial development, the effect of this will be partially offset by a gradual increase of areas under irrigation and by further areas being brought under cultivation as a result of de-rocking. There is also increasing productivity due to the grouping of small planters, increasing mechanisation, more efficient irrigation systems, the introduction of higher-yielding varieties and the adoption of lower-cost methods in field, factory and marketing operations.

The Agricultural Services Department in the Ministry of Agro Industry and Food Security offers a range of support to farmers, including the hire of machinery, provision of improved seeds, the analysis of soil conditions, cold storage facilities and advice where required. They produce their own seeds for distribution to farmers and make over 100 vehicles available, which require management and maintenance. The Irrigation Authority, a parastatal falling under the Ministry, supports more than 5 000 smallholders and six estates in their irrigation endeavours.

The country is moving towards conservation agriculture to optimise production, and the use of chemical fertilisers is being reduced. To grow vegetables efficiently requires the introduction of drip irrigation and nuclear techniques to measure moisture levels in the soil and plants, to determine how much water and nutrients are needed and when. Drip irrigation allows water to be fed to the plants through a network of pipes that deliver water directly to either the base or the root. The process helps to reduce water use.

To further optimise crop yields, and conserve resources, farmers increasingly apply a technique that provides plants with fertilisers mixed with water, a process known as fertigation. Fertiliser using an isotope of nitrogen is applied to a small plot of land to determine the efficiency of the fertiliser and the water uptake by the plants and to optimise the amounts required. The technique can save up to half of the fertiliser traditionally used to achieve the same result.

The country has traditionally been a net importer of food but with the rise in global food prices, much effort has been expended on becoming self-sufficient. With increased productivity, the vegetable crops grown largely under irrigation were said to meet about 98% of the country's demand in 2018. An innovative step is the local cultivation of rice with the aim of supplying the domestic market and for export. It is considered that a 2% annual increase in agricultural productivity is an achievable target for the next decade.

To ensure outlets for local products, Agriculture Services is developing a wholesale market to allow farmers to sell to outlets directly, rather than through a middleman. They are also developing new storage facilities to assist with post-harvest management, and a new slaughterhouse is being developed with significantly greater capacity than the current facilities.

The Food and Agriculture Research and Extension Institute (FAREI) conducts research in non-sugar crops, livestock and forestry, and provides extension services to farmers. The Food Technology Laboratory (FTL) carries out food testing to ensure safe food production at both primary and processor levels. Most units falling under the Ministry expressed the need for additional technical staff.

Forestry

Forests covered some 19% of land area in 2015. Forest resources can be categorised into natural forests which occupy less than 2.0% of the total area and plantations which have continued to reduce over time.

Mauritius is a net importer of timber and is considering the creation of plantations in other countries of the region through bilateral agreements on long-term leases (a similar scheme is in place with Mozambique for sugarcane plantations).

Fisheries

Mauritius has an Exclusive Economic Zone (EEZ) of about 1.9 million km². Tuna fishing is the most important; tuna is caught in the open seas by a range of methods, from handline and longline to purse seining. Aquaculture, the farming of fish, shellfish and aquatic plants in fresh or salt water, is an additional source of supply. Fish farmers produced 485 tons of farmed fish in 2013, consisting mainly of red drum and, to a lesser extent, tilapias.

The fisheries and aquaculture sector has been growing steadily, catering to the growing demand from international markets. The investment-attraction policies have attracted large international players to a wide variety of segments of the value chain, including capture, aquaculture and processing, as well as logistics and by-products development.

MINING AND QUARRYING

There is no commercial mining in Mauritius. Quarrying, however, contributes 0.1% of GDP (2007). The sector is characterised by basalt construction stone, coral sand, lime from coral, and solar-evaporated sea salt. There are around 22 stone-crushing plants in operation. The average tonnage of raw materials crushed daily is 21 550 tons. Stone-crushing plants are essential to the construction industry, as stone is required in the manufacture of ready-mix concrete, concrete blocks and asphalt mix for road surfacing.

MANUFACTURING

The manufacturing sector is the largest sector in the Mauritian economy, contributing 13.9% of gross value add in 2016. The main subsectors are sugar milling, food processing, and textiles and clothing, as shown in Figure 2. The goal for 2030 is that the manufacturing base will be extended to include the development of high-end, precision-driven and technology-enabled industries.

A system of Export Processing Zones (EPZs) was introduced in the early 1970s to provide incentives to stimulate foreign direct investment (FDI) and the transfer of know-how and technology into the country. This initiative has proved to be successful. By the early 2000s, over 500 companies operated in the EPZs, employing over 90 000 workers, representing around 30% of the total workforce.

De-industrialisation is a concern, as liberalisation with the associated reduction in import tariffs has given rise to increasing imports of cheaper products against which local producers cannot compete.

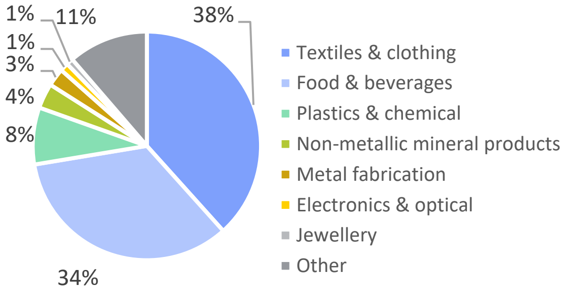


Figure 2: Manufacturing value add per subsector
(Budget Review 2016)

To maximise foreign earnings, a National Export Strategy has been developed, prioritising seven sectors, namely agro-processed foods, fisheries and aquaculture, jewellery, medical devices, cultural tourism, software development and financial services. Airfreight costs for local products to export markets are subsidised by 40% to ensure speed to market.

It has also been recognised that manufacturing for the local market should be encouraged. To develop companies known as Domestic Oriented Enterprises (DOEs) incentives have been put in place for SMEs to access loans to grow their businesses. In 2010 there were some 12 000 small manufacturers, employing some 35 000 workers.

Food, beverages and tobacco products

Mauritius has come a long way from a monocrop economy in the 1960s to fully diversified agro-processing composed of five major subsectors, namely the sugarcane industry, fresh produce (including flowers, foliage, fresh fruit and vegetables), processed foods, seafood and spirits, and beverages.

Food processing includes the range of animal feed and fish pellets, edible oils, wheat flour, margarine, dairy products, pasta, rice, black tea, canned fruit and vegetables, breads and biscuits, and confectionery, among others. There are four sugar mills, two flour mills and a rice mill in Mauritius. Meat and fish processing include canned, frozen, dried, smoked, salted and vacuum-packed products, and, increasingly, breaded, cooked and quick-frozen products to reduce end-user preparation and cooking times.

There are several breweries and beverage manufacturers in Mauritius which manufacture a large range of local beers, wines, spirits, soft drinks, juices, iced tea and bottled water, as well as international brands under licence.

Although tobacco is still grown in Mauritius, production has reduced over the years, particularly after the closure of BAT (British American Tobacco plc) in 2007. The leaves are exported and processed in Kenya.

The main constraints hindering the growth of the food crop sector are the availability of land, the high costs of inputs, labour scarcity, low investment and poor marketing.

Textiles, clothing and leather

Mauritius enjoys a buoyant textile industry which is now one of the main pillars of the country's economy. It is made up of some 285 companies, mostly garment manufacturers, but also spinning and weaving mills, dye-houses and knitting plants, and employs some 52 000 people.

With regard to leather, currently 70% of the raw hides are exported. However, plans are in place to develop the leather sector by boosting local footwear production. With the elimination of taxes on imported footwear in 1996, local companies have struggled to compete. As a result, production has been much reduced, a trend that the country plans to reverse.

Timber, pulp, paper and packaging

The forestry sector accounts for some 10% of industrial production and contributes around 1% to the GDP. There are three main sawmills with an annual capacity of more than 5 000 m³ of round wood, and about 40 small sawmills operating with circular saws. No major investment is envisaged in sawmilling as forest cover is reducing in response to the increasing demand for agricultural, residential and business land.

Construction products include boards, flooring, laminates, plywood, doors, windows, packaging and pallets, all of which are produced locally. The furniture industry, however, relies on imported timbers and reconstituted wood.

Due to the limited plantation resources, paper is imported, from which paper products such as craft and tissue paper, cups and packaging (including cartons, boxes, sacks and bags) are made. Recycling of paper to provide a local source has become important.

Plastics, chemicals and other non-metallic mineral products

Plastic products were first manufactured mainly for the domestic construction industry with PVC replacing iron and mild steel materials in the manufacture of tanks, pipes and many other items. Plastic sheets are produced for use in the agricultural, textile and construction sectors, and the packaging industry makes extensive use of plastic packing material for crates, wrapping of goods, and PET bottles. Rubber dinghies are made locally as well as household goods such as containers, garden furniture, spectacles and goggles.

The chemical sector provides many of the chemicals that are used as basic materials in the manufacturing of end-products such as paper, leather goods, paint, varnish and textiles. The full range of domestic and industrial cleaning products, polishes, cosmetics and personal hygiene products are manufactured, as are speciality chemicals, concrete mixtures and other chemicals used in the construction industry. Fertilisers and pesticides are also manufactured.

Figure 3: Evaporator arriving at the Omnicane Sugar Mill

(Courtesy of Forges TARDIEU ltd.)

All cement is imported, but there are several companies that manufacture concrete products for the construction industry.

Pharmaceuticals

Pharmaceutical manufacturing has grown in recent years. Companies view Mauritius as a platform for targeting mainland Africa. In the 2016–2017 budget, incentives were announced to attract more pharmaceutical companies to manufacture locally; the budget included plans to establish a pharmaceutical village in the south. The focus is on manufacturing generic products in the areas of anti-malarial, cardiology, dermatology, gastroenterology, musculoskeletal, ophthalmology and respiratory treatment.

Computer, electronic and optical products, and electrical equipment

This emerging subsector is driven by the second phase of industrialisation and involves the production of electronic products and equipment, as well as instrumentation and precision engineering products. Mauritius has a pool of qualified technicians who have acquired the knowledge, education and technical skills necessary for the production of high-tech products, such as electronic digital locks, weighing devices, circuit boards, and scientific and laboratory equipment.

The country also produces a wide range of sophisticated medical devices and has progressively expanded its exports, notably to France and India. Many components are imported, but it is intended in time to manufacture components locally.

As part of its bid to move to more high-tech industries, including software development, Mauritius welcomed the opening of a Microsoft App Factory in 2017, the eleventh to be set up in Africa (with others in South Africa, Egypt, Ethiopia, Ghana and Malawi). The App Factory offers opportunities for ICT graduates and developers to build software applications, gain hands-on experience and grow business skills. Many innovative solutions have emerged.

Metal industries, machinery and equipment

The engineering industry has contributed to the growth of the manufacturing sector as a support industry to sugar mills, and to the agro-processing, textile, shipbuilding and construction sectors. The sugar industry has always been supported by heavy engineering workshops in the casting and manufacture of sugar mills. In parallel, small parts were manufactured by several small and medium-sized mechanical workshops for the sugar industry, shipbuilding and the repair of machines and other plants. Expertise gained in the sugar industry has enabled these specialised workshops to export services and the machinery used in the sugar factories throughout the African continent.

The range of products manufactured is extensive, including aluminium utensils and fittings, metal forgings, manhole covers, tools, machinery, equipment, pumps, valves, automotive and machine parts, refrigeration and air-conditioning units, and pipes, etc.

The manufacture of construction materials and fittings is also carried out locally, covering the range of pipes, rebars, sheeting, fencing, partitioning, fasteners, electric cables and fittings such as aluminium and steel windows and doors of various types.

Jewellery

The thriving Mauritian jewellery sector now includes diamond cutting, polishing and processing, manufacturing of gold and silver and precious or semi-precious stone jewellery. The manufacture of watch parts has also become a niche business.

ELECTRICITY, GAS AND WATER

The Ministry of Energy and Public Utilities is responsible for the formulation of policies and strategies in the energy, water and wastewater sectors, and the establishment of a legal framework to govern the development of these sectors. Services are provided through parastatals.

Electricity

Mauritians are in the fortunate position of all having access to electricity, making Mauritius the only SADC country to have achieved this goal. The Central Electricity Board (CEB), a parastatal, is responsible for the generation, transmission, distribution and sale of electricity. The CEB produces around 40% of the country's total power requirements from its four thermal power stations and 10 hydroelectric plants, while the remaining 60% is purchased from Independent Power Producers (IPP)s who largely generate using bagasse from the sugarcane industry and imported coal.

Renewable energy sources are biomass, hydro, solar and wind energy. Biomass energy consists mainly of bagasse and contributes about 22% of the primary supply. Hydropower plants, with a combined installed capacity of 59 MW, have virtually harnessed the entire hydro potential. The wind regime, with an annual average speed of 8.1 m/s at 30 m above ground level in some areas, offers good wind energy potential.

Plans are underway to develop additional generation facilities, upgrade existing facilities and purchase more facilities from IPPs to cater for the short- to medium-term growth. The plans also involve ensuring security of supply and addressing the target of generating 35% from renewable sources by 2025.

The first plant was developed in 1945 and three others in the 1950s. There is now a need to replace these with new, more environmentally friendly and more efficient technology.

To address rural needs, some 293 Small Scale Distributed Generation (SSDG) units had been commissioned by the end of 2014, representing a total capacity of 2.62 MW. Considering the high average annual solar radiation of some 6 kWh/m^2/day, municipal councils are being encouraged to install solar panels for electricity production to meet their needs, thereby reducing the demand for electricity from the CEB.

Due to the uniqueness of the skills sets required, the CEB trains and develops many of its own technical staff through the organisation's in-house training school, the *Centre de Formation et de Perfectionnement Professionnels (CFPP)* and on-the-job coaching. Graduate engineers are offered a two-year training programme through the Ministry of Labour, Industrial Relations and Employment graduate training programme, after which they are free to seek employment elsewhere or apply for any suitable posts that may be vacant at the time.

The Blue Economy

The ocean is an important part of the world economy and offers opportunities for future economic growth, employment and innovation. The Blue Economy focuses on developing sustainable business models relating to the use of coastal and ocean resources, and space. Not only does the Blue Economy create more opportunities for food security through fisheries and aquaculture, but it also creates new technologies.

The Blue Economy also offers alternative energy options for harnessing offshore wind power, wave energy, tidal power and thermal energy conversion. Island nations in particular need to develop these alternative solutions to supplement their limited land-bound resources and reduce their reliance on oil imports. Specialist engineering and scientific training will be required to harness these emerging technologies.

Oil and gas

Mauritius has discovered hydrocarbon fields around its Agalega Island and further investigations are taking place to determine safe and ecological methods for estimating quantities of extractable oil and gas. Mauritius has received permission from the United Nations to extend its continental shelf in order to investigate further afield.

Petroleum products are major imports, with about 1 million tons being purchased per year. Given the availability of renewable sources of energy such as solar, offshore and wind power, Mauritius is working towards reducing its dependence on petroleum products. It is suggested that the country should follow France, Germany, India and others in setting a target date for banning the sale of petrol and diesel cars. There are five main companies in the country's downstream sector that are involved in the distribution and retail of petroleum products.

Water

Mauritians were in the fortunate position of 99.9% having access to safe drinking water, made up of 99.9% of the urban population and 99.8% of the rural population in 2015. The target date for achieving 100% access is 2020.

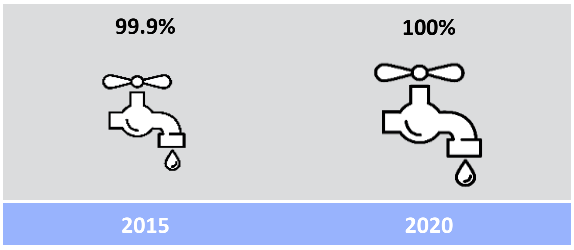


Figure 4: Target dates for access to safe drinking water

Water is supplied by the Central Water Authority (CWA) through six distribution systems, organised geographically, consisting of some 5 000 km of pipe networks, almost 100 reservoirs and many pumping stations and boreholes. The CWA also operates seven water treatment plants.

More than 1 500 km of the network was laid more than 50 years ago and is now subject to frequent leaks and bursts, resulting in significant water and revenue losses, estimated to be as high as 50% in some areas. As a result, the CWA cannot ensure a 24-hour water service. An ambitious investment plan has been developed which includes an increase in treatment capacity, the replacement of old pipes, an increase in reservoir capacity, the upgrading of pumping stations, etc. to ensure 24/7 supply across the island by 2020 and address the need for growth.

Unfortunately, water tariffs are significantly lower than electricity tariffs, which limits the funding available to upgrade and adequately maintain water services.

As only 23% of the annual rainfall of 880 mm to 1 500 mm (depending on locality) is mobilised, plans are in place to increase river abstractions, construct new dams, increase the capacity of existing dams and drill new boreholes. The re-use of treated wastewater for irrigation is also planned. In areas of no network coverage, the Water Tank Grant Scheme has allowed some 32 500 rural households to purchase a domestic water tank to manage their own rainwater harvesting. The Bagatelle Dam was the first of several planned dams to be completed, in mid-2018. It will provide for the water needs of Port Louis and surrounds until 2050.

Concerns were expressed in the water and sanitation sectors that technology in the supply, treatment and monitoring of services has advanced dramatically in recent years, but higher education curricula have not kept up, which requires attention.

Sanitation

Mauritius is unique in that it has a separate Wastewater Management Authority (WMA), responsible for all matters relating to the collection, treatment and disposal of wastewater. It falls under the Ministry of Energy and Public Utilities. The WMA manages the public wastewater system, which consists of 591 km of sewer network, 72 pumping stations and 10 treatment plants.

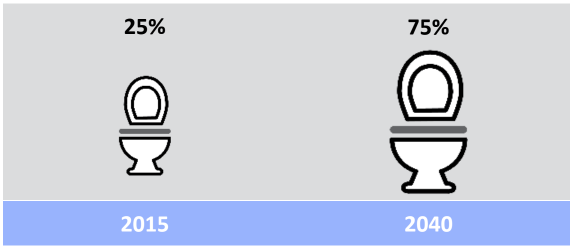


Figure 5: Target dates for access to public sewerage networks (vs improved sanitation)

Although Mauritius has achieved almost 100% access to improved sanitation, only 25% of households have access to the public sewerage networks, the rest have septic tanks which pose health threats due to leaching or overflowing into the aquifers. The National Sewerage Master Plan has a target of increasing those connected to sewerage infrastructure to 75% by 2040. This will require a significant increase in the engineering staff to manage and maintain networks and treatment processes. The WMA reports that it is already facing challenges in employing engineers and technicians as its network is expanding.

TRANSPORT AND COMMUNICATION

Transport and communications remain important lifelines linking SIDSs with the outside world, but land transport presents challenges in terms of space, growth and increasing population density.

Roads

Mauritius has only 2 428 km of roads. With the rising standard of living, the number of vehicles has increased by two-thirds in the space of 10 years and is growing at 7% per year. Infrastructure has, however, not been upgraded at the same pace and conditions have deteriorated, especially in the most densely populated areas of the Port Louis–Curepipe corridor and on the national road network. As a result, the government has identified a series of priority investments including a:

- Road maintenance programme for the national road network
- Ring road around Port Louis and Harbour Bridge to take north-south traffic out of the city
- Bus Rapid Transit (BRT) system from Port Louis to Curepipe to reduce bus travel times and encourage a modal shift to reduce the growing congestion on the road corridor.

Several road projects have been planned, such as the extension of the roadway from Nouvelle France to Plaine Magnien, the implementation of the South Eastern Highway, and the construction of bypasses in areas such as Flacqs, Goodlands and Triolet. Consideration needs to be given to improved design standards when specifying these projects to avoid the landslide conditions that occurred after heavy rains along the Terre Rouge–Verdun motorway which links the centre of the country to the north of the island.

Rail

As of 2017 there were no operational railways in Mauritius. With increasing road traffic congestion, plans surfaced in 2009 for the development of a Metro Express. On 2 August 2017, it was announced that Larsen & Toubro has been awarded the contract to construct the metro network between Curepipe and Port Louis. This 24.9 km line with 19 stations, including six interchanges, would relieve pressure on the busy roads and would be supported by a feeder network of buses. The light rail is a priority project that will deliver economic and community benefits to the nation.

Ports

Port Louis is the main port in Mauritius and Port Mathur is the main port on Rodrigues Island. Port Louis handles 99% of the total volume of external trade and contributes 2% to the GDP.

The Mauritius Port Authority (MPA) is the national ports authority and provides the main port infrastructure and superstructure, together with related facilities. It has embarked on a series of development projects aimed at modernising port infrastructure and facilities, and adding the required capacity to become a regional hub. These projects include:

- Expansion of the container yard to increase capacity from 300 000 to 550 000 TEUs
- Construction of a dedicated oil jetty, for the unloading of petroleum tankers and LPG
- Extension of the existing container berth to accommodate three container ships at any time
- Carrying out dredging works to deepen the navigational channel and the turning basin to a draft of 14.5 m
- Construction of a new Harbour Radio Tower with a modern radio/communication and vessels tracking system to provide a better maritime service and enhance navigational safety.

To cater for traffic beyond 2030, consideration is also being given to the development of an Island Container Terminal to expand capacity further, with a view to commencing construction in 2025.

It was mentioned that various transport-related structures are experiencing a shortage of specialist geotechnical, bridge, rail, marine, coastal and harbour engineers.

Airports

Sir Seewoosagur Ramgoolam International Airport is the main international airport. It is served by some 20 scheduled airlines travelling to more than 30 destinations. A new passenger terminal was inaugurated on 30 August 2013. It is connected to the existing terminal and has a capacity of 4 million passengers. The capacity will need to be expanded to 4.5 million by 2020 and 6 million by 2030, which will involve refurbishing the older terminal and extending the new terminal.

Sir Gaëtan Duval Airport is an airport located near Plaine Corail on Rodrigues Island. In 2006, the airport handled 49 500 passengers. In addition to the Air Mauritius service to Mauritius, Air Austral has started a seasonal service to Reunion's Pierrefonds Airport.

An air corridor between Singapore and Mauritius is envisaged as part of the economic vision to transform Mauritius into one of the Indian Ocean's biggest aviation hubs.

Communications

Reliable international mail, telephone, fax, e-mail, and internet services are available, and plans are in place to install a new submarine cable. The number of free Wi-Fi hotspots will be increased from 15 to 350. The government announced a goal of providing full broadband fibre optic connectivity across the entire island by 2018.

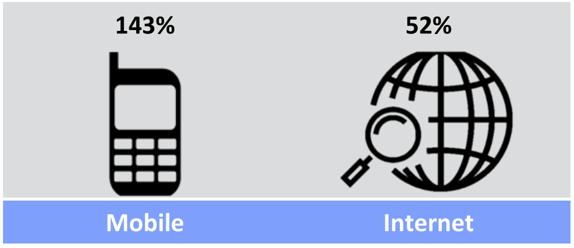


Figure 6: Percentage of population connected to services

The incumbent telecommunications company, Mauritius Telecom, has been partially privatised and benefits from the scale and technical prowess of the Orange Group, which holds a 40% interest. All sectors of the market are open to competition. The country is a hub for submarine cables providing international connectivity, with the IOX Cable expected to be ready for service in 2019 and the LION3 cable providing additional capacity.

The mobile phone market, with 1.8 million users representing a penetration rate of 143% in 2016, is migrating from voice to data services. There are three network operators: Mauritius Telecom, Emtel (operated by the Currimjee Jeewanjee Group and Bharti Enterprises) and Mahanagar (a subsidiary of MTML), which is also the island's second fixed-line operator using CDMA2000 technology. These operators have steadily increased the reach of their LTE infrastructure to support growing demand for mobile data services.

Around 30% of the population are connected to fixed-line telephone services, which is still steadily increasing from previous years. In the broadband sector there is continuing progress in developing FTTC and FTTP rollouts. Mauritius Telecom has invested more than Rs 5 billion to fast-track national FTTP deployment. The country is very proud to be in the top 10 countries in the world, and the highest in Africa, in terms of the percentage of those connected through FTTH. In 2015, 52% of households were connected to the internet, 55% of whom were connected via FTTP and it is expected that all households will be connected by 2022.

The ICT sector is a key driver of the economy, with a contribution of 5.5% to gross value added in 2016, employing over 23 000 people and underpinned by leading global companies. Over the last decade, internet connectivity speed has increased ten-fold, while internet tariffs have reduced by up to 70%. The government aims to accelerate the transformation of Mauritius into a digital economy and society.

Mauritius Telecom is the largest employer of engineers in the country. They are involved in a range of activities, not only expanding the network, but also developing Apps to prepare the country for the Fourth Industrial Revolution and the Internet of Things.

CONSTRUCTION

Construction is important in any country due to its ability to create jobs and develop skills. The Mauritian construction sector has received a stimulus of Rs 130 billion to be invested in public infrastructure from 2017 to 2026. Major projects are shown in Table 2. This will lead to an unprecedented demand for a skilled labour force and a steady supply of basic construction materials.

The development of Smart Cities will further stretch the sector. These developments will include the construction of world-class offices, retail facilities, light industrial infrastructure and residential precincts, and the provision of incentives, logistics and access to freeport facilities. Developments are ongoing in Mon Tresor, Cap Tamarin, Moka, Mauritius Jinfei and Medine. It is hoped that this will attract international investors and many innovative high-tech businesses to set up in Mauritius.

Procurement regulations are of concern to local contractors. The different bidding methods allow a public sector organisation to call for:

- **National bids** for projects under Rs 200 million – this limits bidding to Mauritian companies
- **Advertised bids** for projects under Rs 200 million – under this option bids may be open to everyone
- **International bids** for projects over Rs 200 million – under this option bids must be open to everyone.

With open bids, the competition is fierce and contracts are generally won by international contractors, particularly those supported by their governments. Pricing is based on using skills, materials and equipment from the bidding country, which impacts on manufacturing and job opportunities in Mauritius. At present there are no specific trade restrictions as far as construction materials are concerned.

Concerns have also been expressed by local contractors about the preferential treatment given to international contractors in terms of allowing staff to live on site and paying lower than the minimum wage specified for Mauritian contractors. The April 2018 *Market Study of the Construction Industry in Mauritius* has called for input from the sector on practices that are limiting their opportunity to win projects or grow their organisations. It is hoped that the legislation will be adjusted to be more supportive of local service providers.

Table 2: Major projects identified, or being planned or under construction

PROJECT		VALUE US$	START YEAR	END YEAR
Energy	Setting up of a 120 MW Combined Cycle Gas Turbine (CCGT) Power Plant	$236m	2018	2022
Water	Renewal of water pipes		Ongoing	
	Rivière des Anguilles Dam and Water Treatment Plants	$95m	2016	2018
	Bagatelle Dam and Bagatelle Water Treatment and associated works	$245m	2016	2019
Ports & airports	Berth Extension and Strengthening at Mauritius Container Terminal (MCT) - Phase 1	$196m	2016	2019
	Construction of a fishing port at Fort William	$40m	2019	2022
	Passenger Terminal Expansion at SSR International Airport, new control tower, upgrading of old terminal, etc.	$220m	2018	2024
Rail & road	The Metro Express	$1.6bn	2017	2022
	Reconstruction of Jumbo Phoenix Roundabout and A1 M1 Bridge	$132m	2017	2021
Other	New Flacq Teaching Hospital	$128m	2019	2021
	Multi Sports Complex at Cote D'Or	$112m	2018	2022
	Social housing	$612m	2018	2024

Housing

In 1991 a decision was taken to develop flats to house low- and lower-middle income households. However, a minimum payment was required to acquire a unit, and with rising construction costs, these units became unaffordable.

According to the 2011 Housing and Population Census, there were 356 900 housing units with a backlog of around 17 000 units, assuming one household to be housed in one housing unit. The backlog was to be tackled by building 5 000 houses from 2011 to 2016 and at least 3 000 every five years thereafter. Bold measures featured in the 2015/2016 budget, with the objective of meeting the challenges of housing for the low- and middle-income groups. Among these measures were:

- The provision of funds to the Ministry of Housing and Lands for the construction of 1 000 low-cost housing units for families whose monthly income is below Rs10 000
- An increase in the size of these housing units from 39 m² to 50 m²
- An increase in the grant for casting roof slabs and the purchase of building materials for families earning up to Rs10 000 monthly.

LOCAL GOVERNMENT

There are five municipal councils in the urban areas and seven district councils, under which fall 130 village councils. The engineering functions assigned to local authorities under the Local Government Act, No. 36 of 2011, include the responsibility of planning spatial layouts; handling building control and approvals; developing and maintaining community services, including libraries; nurseries for infants; pre-primary schools; recreation areas and places of entertainment; public buildings and amenities such as markets; roads, associated drainage, bridges and street lights; cemeteries and emergency services; and the collection of solid waste. Local authorities may also be called upon to manage and maintain assets handed over by any Ministry or Government Department.

The supply of water, removal and processing of sanitation, and the supply of electricity are handled by the utilities, while the disposal of waste is the responsibility of the Solid Waste Management Division of the Ministry of Local Government and Outer Islands. The processing is handled by a private contractor who compacts and transports the waste to the Mare Chicose Landfill site. Water and electricity are purchased by municipalities for use in amenities, parks, etc.

The number of assets and the levels of service required continue to increase, with the resultant increase in workload. The number of engineers and technicians in local authorities has, however, reduced over time, with two districts no longer having any engineering staff and two districts with only one civil engineer. Districts and municipalities serve populations ranging from 50 000 to 350 000, all of whom need the services listed above. Engineers who have remained in local government have a limited say in project prioritisation, as this is often dictated by Councillors, to the detriment of key projects and, invariably, operations and maintenance.

Local authorities, along with other government departments, have committed to taking on engineering graduates for the two-year cadetship period working towards professional registration. When the contracts are over, there is no way of appointing candidates with high potential in local government, as there is no provision for them in the structures. Without internal capacity, work is outsourced to consulting engineers and contractors who are not necessarily up to speed on municipal requirements, and little or no oversight takes place on the projects undertaken.

Of great concern is the fact that there is only one electrical engineer employed in Mauritian municipalities, despite there being some 150 000 street lights and many buildings and amenities requiring the design, commissioning, operation and maintenance of electrical services. There is also limited capacity to manage the extensive fleets used in local government.

Municipal organograms need to be reviewed and funding needs to be made available to accommodate the additional disciplines and posts required, and to place the Head of Public Infrastructure in a sufficiently elevated position to make key decisions on the budgets and prioritisation of spending.

Historically, scarce skills allowances were paid for engineering skills in local government, at which time the number and calibre of engineers increased. But since allowances have been withdrawn, the number left in local government has reduced to unacceptably low levels. A review of the salary levels is urgently required to attract and retain high-calibre municipal engineers. This should not be in the form of allowances, as the associated increase in benefits does not accrue unless the base salary is increased.

City design is set to change with the introduction of the 'Smart City Scheme' which will allow people to 'work-live-play' without long commutes and use technology to maximum advantage. This will need to the considered in future plans.

EDUCATION, TRAINING AND PROFESSIONAL DEVELOPMENT

Education and training is a vital part of developing engineering capacity. All elements, from teaching appropriate subjects at schools, to continuing professional development (CPD), need to be in place to educate, train and ensure that engineering personnel remain abreast of the latest technology, challenges and emerging solutions.

It is considered that inadequate skills constitute a major constraint on the country diversifying and increasing its competitiveness. The supply of technical and vocational education and training remains limited, and there is too much emphasis on low-skilled training programmes.

The tertiary education sector is being called upon to emerge as a strong pillar of the economy. In particular, curricula need to be reviewed systematically and more regularly to respond to the growing need for skills and the requirements of emerging economic sectors.

PRIMARY AND SECONDARY EDUCATION

Primary education spans six years. Passing the Certificate of Primary Education (CPE) examination is a prerequisite for proceeding to secondary education, and high achievers compete to attain the best results for entry into prestigious secondary institutions.

Secondary education is broken into five years, termed 'middle education', after which O-level examinations are written, followed by an optional two years, after which A-level examinations are written, administered by the University of Cambridge (UK). With the change in teaching methodologies over the years, and changes in the interests of learners, tertiary education institutions and the engineering fraternity have expressed concern at the decline in interest and results gained in A-Level mathematics and science.

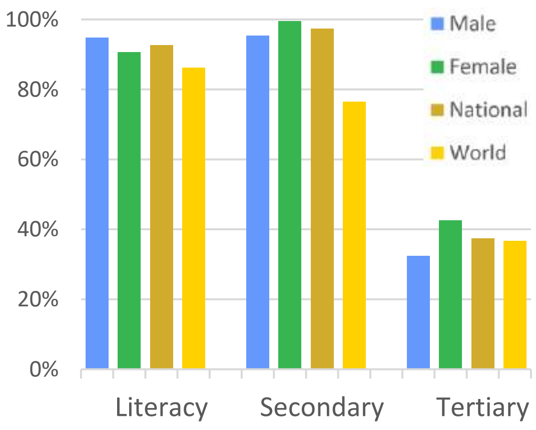


Figure 7: Literacy and enrolment statistics
(UNESCO 2015)

Analysing the high dropout rate from those starting school to completing secondary school (only 28% of the Grade 1 learners commencing in 1994 completed secondary education in 2006) gave rise to the Education and Human Resources Strategy Plan (2008–2020) to address the weaknesses in the system. There are plans to redevelop curricula and restructure formal schooling to nine years, after which learners will be streamed into vocational or academic streams, in recognition of the fact that every Mauritian must be equipped with skills to combat poverty and support greater upward social mobility.

TERTIARY EDUCATION

Tertiary education in Mauritius includes colleges, universities and other technical institutions. In 1992 the University of Mauritius (UoM) was the only university offering engineering qualifications. The government has since increased the number of public institutions and created space for private institutions both to train local students and become a centre of choice for foreign students. The target is 100 000 foreign students.

In 2000, the University of Technology (UTM) was the second public university to be established and in 2012, the Open University of Mauritius (UO) was the third. The Université des Mascareignes (UDM) was the fourth to be formed after a merger between the IST (Institut Supérieur de Technologie) of Rose-Hill and Swami Dayan and Institute of Management (SDIM) of Pamplemousses.

The Mauritius Institute of Training and Development (MITD) was formed in 2009 to consolidate the activities of the Industrial and Vocational Training Boards, and the Lycée and other colleges that fell under the Technical School Management Trust Fund. Most of the programmes are vocational in nature, but national diplomas and higher national diplomas are offered. The latter is at NQF 6 level. Other TVET Colleges use City and Guilds qualifications for vocational training. The Vocational Training Institute Ltd is the only college to offer a City and Guilds Level 5 Advanced Technician Diploma, which aligns with the requirements of the Dublin Accord and is at

NQF level 6. All other engineering TVET college qualifications are offered at lower NQF levels.

In the utilities, career progression is from technician and technical officer with a diploma, to senior technical officer and principal technical officer with an advanced diploma. NQF Level 5 qualifications do not form part of this study and are not included in the totals.

The institutions offering engineering qualifications are shown in Table 3. The JSS Academy of Technical Education offers engineering qualifications which are not at the engineer level, but students may complete additional courses over 2.5 to 3.5 years at the UTM to qualify as engineers. The JSS graduate numbers are shown under UTM in Table 3. Several international universities have started offering qualifications in Mauritius, but no students had graduated by 2015, hence NQ in the table for None qualified. The graduation trends are shown in Figure 7 and the split by discipline, category and gender in Figure 8.

Accreditation of engineering programmes

Each public institution is established through an Act of Parliament and must develop statutes and regulations which define the powers and functions, delivery methods and the approaches required for the development of qualifications. The Tertiary Education Commission (TEC) has the responsibility of fostering, planning and coordinating the development of education and training offered by private institutions. Before offering a qualification, an institution must apply to the TEC for recognition and programme accreditation.

Table 3: Engineering graduations in Mauritius in 2015

INSTITUTION	QUALIFCATION	Chemical	Civil	Electrical & Electronics	Industrial	Mechanical & Mechatronics	Telecommuni-cations
Public institutions							
Université des Mascareignes (UDM)	BEng (Hons)		80	42		48	
	Diploma		19	74 (2014)		12	
University of Mauritius (UoM)	BEng (Hons)	72	56	54	NQ	110	
	BSc		24	22		110	
	Diploma		2				
University of Technology (UTM)	BEng (Hons)		9 (2012)	11 (2012)			19
Mauritius Institute of Technical Development (MITD)	HND			6			7
Private institutions							
Middlesex University Mauritius				NQ			
Rushmore			NQ				
Vocational Training Institute Ltd	Adv. Diploma (NQF level 6)			19		9	
TOTAL							
BEng (Hons) (501)		72	145	107		158	19
BSc (156)			24	22		110	
Adv. Diploma/HND/Diploma (148)			21	99		21	7

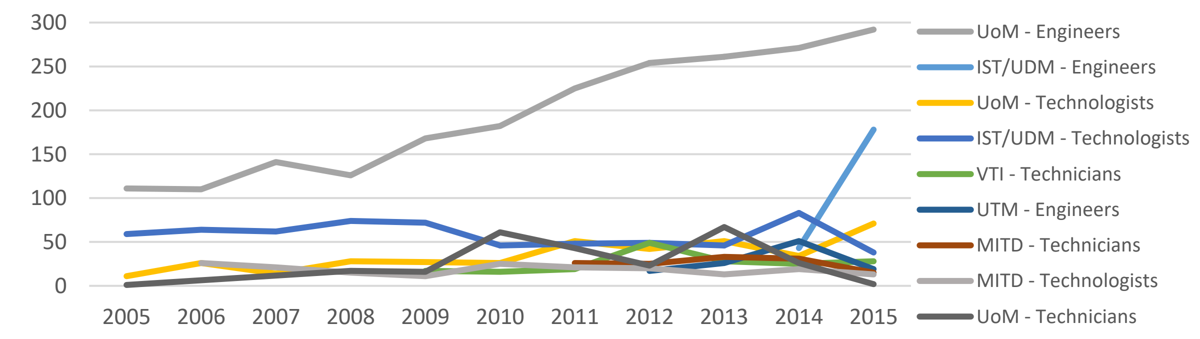


Figure 8: Engineering graduates by institution and category

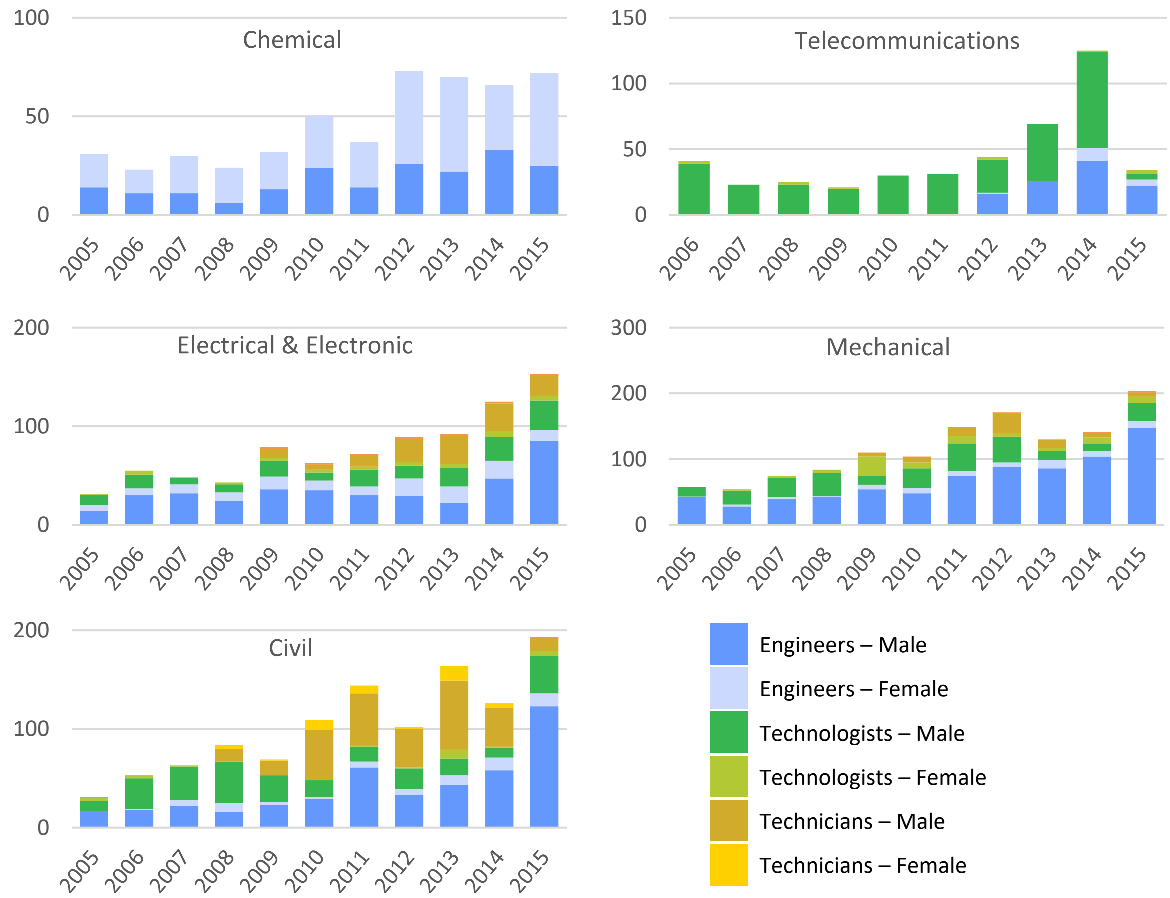


Figure 9: Engineering graduates by discipline, category and gender based on selected institutions as per Figure 8

Criteria such as governance, human and infrastructure capacity, teaching and learning methods, and the range of academic programmes are considered, and each programme is reviewed by subject specialists, academics and technical staff. Professional bodies usually provide the expertise to carry out the accreditation process for associated professional programmes. In both private and public institutions, the Council of Registered Professional Engineers (CRPE) must approve the qualifications as meeting its requirements for the practise of engineering. In the past the CRPE only recognised graduates from UoM and those accredited by the Engineering Council in the UK.

With the increase in the number of engineering programmes on offer, there is a desire to ensure that the standards are equivalent to and compete with the best internationally. Mauritius has thus embarked on a process of adopting the Washington Accord guidelines from the International Engineering Alliance (IEA) for accrediting engineering degrees.

To do this, an Engineering Accreditation Board (EAB) is being set up, independent from the professional registration body, to accredit and ensure the standard of engineering education. Understanding the requirements, setting up policies, guidelines etc., and training accreditors is a lengthy process. It is expected that it will take until 2019 to achieve provisional status, and a further five years to be formally recognised under the Washington Accord. This will further support the Mauritian plan to become the regional hub for higher education.

The TVET sector is managed by the Mauritius Qualifications Authority (MQA) which registers training institutions, managers, programme officers and trainers, and approves courses as well as accredits training institutions and courses. The National Qualifications Framework (NQF) ranges from levels 1 to 10 where O-levels are at level 3 and A-levels at level 5. Those following a vocational career would exit school at O-levels and complete a two-year diploma or three-year advanced diploma. In terms of the levels recognised for the registration of technicians and technologists in other SADC countries, the advanced diploma would be considered as the minimum requirement for registration as a professional technician.

MAURITIUS

Student mobility

In 2015, 716 Mauritians were studying at South African universities, 281 of whom were studying by correspondence through the University of South Africa. A total of eight engineering students graduated, all eight completing degrees.

The government offers scholarships for engineering students to study locally or abroad, but they must return to the country to work back the investment made in them. Over the years, more than 50% of all Mauritian engineers have studied abroad, with 19% having studied in the UK, 14% in India, 4% in France, 3% in Russia, 2% in South Africa, and smaller numbers in countries such as Pakistan, Australia, Canada, Kenya, Malaysia, Korea and the USA, among others.

In addition, the government offers scholarships for foreign students to study in Mauritius and is encouraging countries with inadequate higher education capacity to use Mauritius as their country of choice. Some 6% of the engineering students currently studying at the University of Mauritius are foreign, mostly from neighbours Madagascar and the Seychelles, along with others from Kenya, Uganda and India.

GRADUATE TRAINING

The CRPE requires all candidates for registration as Professional Engineer to complete a satisfactory period of engineering training and satisfy the competence standards set by the CRPE. Applicants must show that they have an accredited qualification, have undergone approved professional training and, at the professional interview, must demonstrate their engineering competence against specific criteria. Sadly, graduates complain of the difficulty in gaining meaningful employment.

To try and address the unemployed graduate challenge, the government has created the Youth Employment Programme (YEP). It is possible for graduates to apply for support, or for companies to approach the YEP for suitable graduates to take on for a period of two years. During this period, the employer is expected to train graduates towards the competence expected of their profession. The programme pays the stipend for graduates, if the employer is from the public sector and 50% of the stipend for private sector employers. The YEP also contributes towards the costs of supplementary training considered necessary during the period, as long as it is recognised by the MQA. The challenge is to ensure that graduates follow a structured programme of meaningful work to achieve the outcomes expected by the CRPE. It is important that mentors are in place to monitor the process.

Although remote mentorship is permitted, access to mentors remains a problem. As part of its service to the profession, the Institution of Engineers Mauritius (IEM) is currently setting up a register of mentors who would like to volunteer their services.

PROFESSIONAL REGISTRATION

The CRPE was set up under the Registered Professional Engineers Council Act (RPEC Act), No. 49 of 1966, to regulate the engineering profession and maintain engineering standards in line with internationally recognised standards of professional competence and ethics.

Currently, the CRPE registers suitably qualified applicants on the CRPE Roll of Engineers. The Roll has only one category – Registered Professional Engineer. This title is protected by the Act, as well as the abbreviation 'RPEM' and additional titles 'Registered Engineer', 'Professional Engineer' and 'Engineer'.

There is a legal restriction on the right to practise as an engineer in Mauritius. Registration is renewable annually and is mandatory for engineering employment and the provision of engineering services involving design and decision-making. Registration is also a requirement for appointment in any engineering public sector post. By law, however, it does not apply to operating, executing or supervising any works as owner, contractor, superintendent, foreman, inspector or master, or other roles not associated with design. Thus, the number of registered engineers in the manufacturing sector is likely to be low, as they are generally managing production processes. However, those organisations that sell to the government must employ professional engineers to satisfy procurement requirements.

By September 2018 there were 851 paid-up registered engineers, as shown in Table 4. It is believed that this represented some 30–40% of all engineers in Mauritius. Those not registered are generally recent graduates being trained under the supervision of a registered engineer, academics and researchers, those working in IT and computer systems, and about 30% who do not need to take responsibility for the final projects on which they are working, although this category should be incorporated into future legislation.

Technicians are not registered by the CRPE and are considered as support staff in the engineering team. They are generally found working in construction, as

Table 4: Registrations with the CRPE 2018

DISCIPLINE	NUMBER
Aeronautical Engineering	3
Agricultural Engineering	1
Bio-medical Engineering	2
Building Services Engineering	3
Chemical & Environmental Engineering	16
Civil Engineering, including Structural	429
Electrical & Electronic Engineering	228
Electro-mechanical & Mechatronics	16
Electronic & Telecommunications	28
Industrial Engineering	3
Mechanical Engineering	122
TOTAL	**851**

technical officers and inspectors or in operations and maintenance. It is estimated that there are some 3 000 technicians with various qualifications ranging from HND, HNC, City and Guilds Full Technological Certificates and the lower Final, Part 2 or Part 1, diplomas from the Polytechnics (local and overseas) and diplomas from the University of Mauritius, etc.

VOLUNTARY ASSOCIATIONS AND CONTINUING PROFESSIONAL DEVELOPMENT (CPD)

The Institution of Engineers Mauritius (IEM) was founded in 1948 and has a very active membership of technicians, corporate and associate members, fellows and students. It sees its role as that of:

- Fostering engineering science and its application in all engineering disciplines
- Ensuring the highest standard of service in engineering
- Improving the status and safeguarding the interests of the engineering profession.

They have been quoted as saying, *'The Institution of Engineers Mauritius is convinced that the future of Mauritius and of the world is in the hands of Engineers'*, demonstrating their passion for developing engineers and contributing to solutions.

Recognising that there is a need for registered professionals to keep up to date with the latest technology, legislation, trends, etc., the IEM has set up a Training Centre which was registered as a training institution by the MQA in March 2015. The Centre started its activities in February 2016, and in the short term aims to organise three to four short courses per year. In the long term, it plans to offer advanced specialist courses, if required, in collaboration with overseas institutions.

The IEM also organises talks on specialist topics, and site visits to see major ground-breaking engineering works undertaken. From time to time, it publishes newsletters covering its activities and challenging Mauritian engineering practitioners to contribute to the national thinking on sustainable engineering solutions. The IEM has also set up a new committee on innovative engineering initiatives to highlight and encourage research in engineering fields.

Several branches of British Institutions are also active in Mauritius to support engineers in specific disciplines, such as the Institution of Civil Engineers (ICE), the Institution of Mechanical Engineers (IMechE), the Institution of Engineering and Technology (IET) and the Aeronautical Society, whose local branch is known as the Aeronautical Society of Mauritius (AESM).

WOMEN IN ENGINEERING

There are no specific Women in Engineering initiatives in Mauritius, although the universities work hard to attract female students to enter engineering studies.

THE WORKFORCE

It is estimated that a total of 5 000 engineering practitioners work in the country. Figure 10 shows the distribution of engineers by age and gender. In the absence of technician registration, the profile of technicians is unknown, but is likely to follow a similar profile.

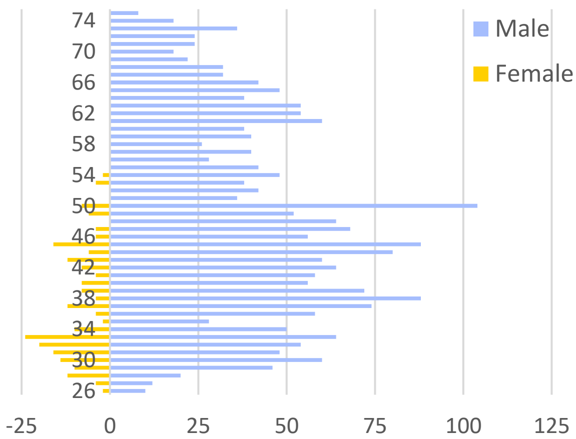


Figure 10: Engineers in the workforce by age and gender based on CRPE data

THE PRIVATE SECTOR

The main employers in the private sector are consulting, contracting and manufacturing companies, suppliers and quarries. Lower numbers are employed in small entrepreneurial companies, NGOs, training organisations and other companies where engineering input is required.

Table 5: Consulting engineering companies registered with the CIDB in September 2018

DISCIPLINE	Local	Provisional foreign	Provisional JV local dominant	Provisional JV foreign dominant	Temporary	Total
Civil Engineering	26	204	11	45	14	300
Mechanical Engineering		50	4	12	1	67
Electrical Engineering		50	6	14	1	71
Project Management	23	75	10	21	5	134
MEP Services	21	26		6	6	59
Multiple fields		67	8	32	17	124
TOTAL	**70**	**472**	**39**	**130**	**44**	**755**

Consulting

The Association of Consulting Engineers of Mauritius (ACEM) is a voluntary association which brings together companies that provide consulting engineering services in Mauritius. Through the association, members are able to interact and advance their interests. There are some 70 local consulting engineering firms registered with the Construction Industry Development Board (CIDB) as shown in Table 5, employing about 400 engineering practitioners locally. Foreign companies may not bid for projects unless they are provisionally registered with the CIDB, and once awarded a project, they must apply for temporary registration for the duration of the contract. The number of temporarily registered foreign companies working in Mauritius has increased from 12 in 2016 to 44 in 2018.

Consulting engineers expressed concerns about the conditions of contract relating to projects financed by foreign governments, which require that only service providers from the funding country may bid for the work. Competition is thus fierce for the remaining work, with fees as low as half of the value of the work being quoted. Low fees limit the time spent on investigating alternative options and developing optimum solutions. Limited fees also have an impact on the time spent on site supervision and on monitoring the quality of the work carried out.

Furthermore, designs done outside the country are not vetted by locals in terms of suitability and recognition of local conditions. Regrettably, Mauritius does not have a full set of local design codes and standards to enforce, hence designs are at times done in accordance with the funder country's codes and standards. Given the cyclonic conditions, the nature of the soil and many other unique variables, this has given rise to various failures, the most recent being the failure of large stretches of the Terre Rouge–Verdun motorway. Consideration should be given to developing a suite of local standards, the use of which should be enforced on all contracts.

Contracting

The CIDB is a statutory body established under the CIDB Act, No. 35 of 2008, amended in 2016. The objective of the CIDB is to promote the development and improvement of the construction industry. The CIDB falls under the Ministry of Public Infrastructure and Land Transport, and aims to provide leadership towards the development of a world-class construction industry. One of the core activities of the CIDB is the registration of contractors and consultants – no person or company may offer their services unless registered. The Act makes provision for the registration of both local and foreign contractors and consultants. Foreign companies may not bid for projects unless they are provisionally registered with the CIDB, and once awarded, a project must apply for temporary registration for the duration of the contract. More than 100 foreign contractors are registered provisionally or temporarily, more than 70% of which fall in category A. In September 2018 there were 1 154 contractors employing some 56 000 in the construction sector, as shown in Table 6.

Contractors are graded on the basis of their financial capabilities and the nature of the projects they can undertake. It is estimated that around 400 engineers and 800 to 1 000 technicians are employed in the sector.

Table 6: Local contracting companies registered with the CIDB in September 2018

GRADE (Rs million)	Building construction works	Civil engineering construction works	MEP works	Total
A (Above 200)	13	12	15	40
B (Up to 200)	4	1	4	9
C (Up to 100)	13	3	12	28
D (Up to 50)	26	15	18	59
E (Up to 20)	48	15	25	88
F (Up to 10)	46	21	24	91
G (Up to 4)	105	40	25	170
H (Up to 1.5)	452	137	80	669
TOTAL	**707**	**244**	**203**	**1 154**

The Building and Civil Engineering Contractors Association (BACECA) was set up in 1996 to safeguard, encourage and protect the interests of its contracting companies and deal with any matters that may affect members or the construction industry. The Mechanical and Electrical Engineering Contractors Association (MEECA) is a similar organisation representing the interests of mechanical and electrical engineering contractors.

Manufacturing

The manufacturing sector is an economic pillar, contributing 13.9% to the GDP in 2016 and employing approximately 111 700 workers. In terms of large establishments, there were some 280 Export Orientated Enterprises (EOEs) and 300 Domestic Orientated Enterprises (DOEs) making up the bulk of the production in 2016. There are also thousands of small units employing between one and three people, usually family members and/or friends, involved in small and micro manufacturing activities. They make up about a third of the manufacturing workforce.

There is a vast difference between the focus of DOEs and EOEs. The bulk of DOE production is focused on food, beverages, chemicals, plastics, metal and other products for local use, while the bulk of EOE production is focused on textiles and clothing for export. As most of the textile industry is Cut, Make, Trim (CMT), and limited yarn or fabric production takes place, it is assumed that only 10% to 20% of EOEs will employ an engineer or technician, and it is assumed that DOEs will require an average of two to three engineers and/or technicians to manage processes, quality and production in general.

In terms of the larger production units, the 2012 Human Resource Development Council (HRDC) study on labour shortages in the manufacturing sector listed chemical, electrical and mechanical engineers as being in short supply.

The Association of Mauritian Manufacturers (AMM) represents the interests of manufacturers. They have launched the *Made in Moris* brand (Made in Mauritius in Creole), which encourages the locals and tourists to purchase local products and support DOEs. The Mauritius Chamber of Commerce & Industry (MCCI) promotes the interests of the business community, many of which are manufacturers.

The Economic Development Board (EDB) of Mauritius is a new parastatal body responsible for promoting Mauritius and attracting investments. The Board of Investments, Enterprise Mauritius, Mauritius Africa Fund and the Financial Services Promotion Agency have been integrated into the EDB.

Mining and quarrying

There are around 22 stone-crushing plants in operation, which employ a few engineers and engineering technicians.

THE PUBLIC SECTOR

Many engineering practitioners are required in the public sector, including in municipalities, to plan new services, issue project tenders and oversee project delivery, and operate and maintain infrastructure Table 8 shows the ministries that are the main employers of engineering skills.

Over time, many services have been outsourced or privatised. Most ministries rely heavily on consulting engineers and contractors for service delivery. Of concern is the fact that at times the scopes of work and tender documents are also drawn up by service providers or funders, and there is limited opportunity to oversee and ensure that quality final solutions are delivered. Public sector employees complain that their professional judgement is not valued, with technical decisions often being made by non-technical managers or even politicians.

In both the public and private sector there is said to be a gap between the senior experienced engineering staff and junior staff. Although the graduate programme has been put in place to develop graduates towards professional registration, succession planning thereafter is limited. There are no programmes to develop young professionals into management or technical leadership roles, and there is limited support for continuing professional development (CPD). Those who do follow post-graduate studies of their own accord generally study overseas and often do not return.

The outsourcing of projects and appointing of international companies to carry out major projects limits the opportunities for young professionals to gain the requisite experience. Mauritian public sector staff at all levels should be harnessed in all projects, whether awarded to local or international organisations. To retain the older experienced staff, the retirement age was moved from 60 to 65 years old in 2016.

Departments complain of high levels of vacancies, in some cases up to 100%, citing poor salaries, extreme workload, responsibility and the lack of career development opportunities as major causes. No increases are paid to graduates once registered, and limited promotion opportunities exist. Consideration

MAURITIUS

Table 7: Ministries employing engineering practitioners

MINISTRY/STRUCTURE
Ministry for Rodrigues and National Development Unit
Ministry of Agro Industry and Food Security • Department of Agricultural Services • Food and Agriculture Research and Extension Institute (FAREI) • Irrigation Authority (IA) • The Food Technology Laboratory (FTL)
Ministry of Education and Human Resources, Tertiary Education and Scientific Research • Tertiary Education Commission (TEC) • Mauritius Qualification Authority (MQA)
Ministry of Energy and Public Utilities • Central Energy Board (CEB) • CEB (Green Energy) Co Ltd • Mauritius Renewable Energy Agency (MARENA) • Central Water Authority (CWA) • Wastewater Management Authority (WMA)
Ministry of Environment, Sustainable Development, and Disaster and Beach Management
Ministry of Housing and Lands • Mauritius Housing Company Ltd
Ministry of Industry, Commerce and Consumer Protection • Economic Development Board (EDB) • Mauritius Standards Bureau (MSB)
Ministry of Labour, Industrial Relations, Employment and Training
Ministry of Ocean Economy, Marine Resources, Fisheries, Shipping and Outer Islands • Mauritius Oceanography Institute (MOI)
Ministry of Public Infrastructure and Land Transport • Road Development Authority • Construction Industry Development Board • Council of Registered Professional Engineers (CRPE) • National Transport Authority (NTA) • National Transport Corporation (NTC) • Traffic Management and Road Safety Unit
Ministry of Technology, Communication and Innovation • Mauritius Telecom (in partnership with Orange) • Mauritius Broadcasting Corporation (MBC) • Information and Communication Technologies Authority (ICTA) • Mauritius Post Limited • Mauritius Research Council
Ministry of Local Government and Outer Islands • Five Municipalities (Port Louis, Vacoas-Phoenix, Beau Bassin-Rosen Hill, Curepipe, Quatre Bornes) • Seven District Councils (Savanne, Moka, Riviere du Rempart, Flacq, Pamplemousses, Grand Port, Black River) • Solid Waste Management Division
Prime Minister's Office • Ports Authority • Department of Civil Aviation • Metro Express • Meteorological Services • National Development Unit
Statistics Mauritius

should be given to adding a higher salary band to each level for engineering salaries and other professional skills that are in high demand, and succession plans with associated training and development plans need to be developed for all engineering staff. An allowance for scarce skills was paid to the end of 2016, which was not considered adequate, but has since been withdrawn, which is cause for concern. All these policy decisions are in the hands of the Pay Research Bureau (PRB).

Other challenges experienced by the public sector include the complexity and protraction of the procurement processes, with decisions often being made on price or by non-technical people, and the lack of budgets for maintenance. In the long term this will cost the country significantly more for repairs and upgrades than the cost of routine and preventative maintenance.

MIGRATION TRENDS

Analysis of the United Nations Population Division statistics for 2015 shows a net loss of professionals from Mauritius. Of those entering the country, 27% were from India. Thirty-seven per cent of professional emigrants moved to the UK and Northern Ireland, 16% to Australia, 14% to Canada and 12% to France.

These statistics relate to those who have officially immigrated or emigrated. There is, however, a constant flow of engineering skills as contracts are awarded to international contractors, who enter on a temporary basis. The current distribution of foreign nationals working in Mauritius and registered with the CRPE are shown in Figure 11.

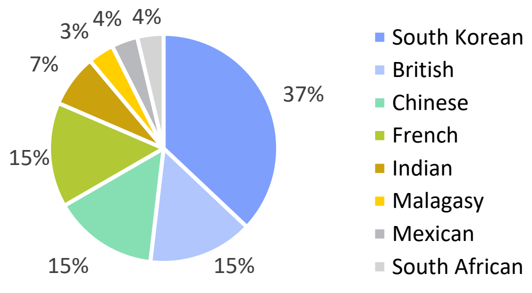


Figure 11: Percentage distribution of foreign engineers registered with the CRPE

ENGINEERING NUMBERS AND NEEDS

The change from a poor to an upper middle-income country has been strategically driven for many years. It could not have been achieved without dedicated

Table 8: Estimated numbers of engineering practitioners in the engineering workforce

SECTOR	ESTIMATED NUMBER
Academia and research	350
Agriculture	50
Consulting	400
Contracting	1 400
Government	1 400
ICT, systems and telecommunications	500
Manufacturers and suppliers	600
Quarrying	50
Miscellaneous and NGOs	250
TOTAL	**5 000**

engineers to plan and deliver the massive engineering developments that have taken place, including the growth of manufacturing and the development of the road, electrical, water and telecommunications network, ports and airports.

Considering all the sectors in which engineering practitioners have been active suggests there are approximately 5 000 in Mauritius, as shown in Table 8. It should be noted that these figures are estimates built from discussions with each sector, but do not represent detailed survey results.

Figure 12 shows the current workforce, the losses that will occur over the 18-year period to 2035 due to retirement, mobility and mortality, and the growth in engineering capacity if engineering graduations increase at 2% per year over the period. It is assumed that 500 engineers are ready to enter the workplace, 160 technologists and 150 technicians, based on the graduations shown in Table 3. An allowance of an additional 80 entering the workplace from 2020 is included to cover those graduating from new qualifications.

The blue dotted line shows the growth in skills that would be required at the 2017 GDP growth rate of 3.9%, and the green dotted line shows the growth based on the 2018–2022 GDP projection of 4.0%. (Being so similar, these are difficult to differentiate in the figure.) A 70% employment elasticity factor has been used to extrapolate the employment demand.*[1]

The projection shows that there will be an excess of graduates if growth is limited to 4%. This will not be a problem if a significant proportion of the engineering graduates are international students. To attract this number, it will be essential for the Mauritian engineering qualifications to be recognised under the Washington Accord.

If the number of graduates relate only to Mauritians, the increased number graduating can only be absorbed if the growth ranges between 7% and 8% per year. Should the country continue business as usual and use only 5 000 engineering practitioners, there will be many unemployed engineering graduates. To absorb these graduates and grow the workforce, it will be necessary to grow the YEP programme to place more graduates in both the public and private sectors.

When rationalising or reviewing the qualifications offered, consideration needs to be given to industry

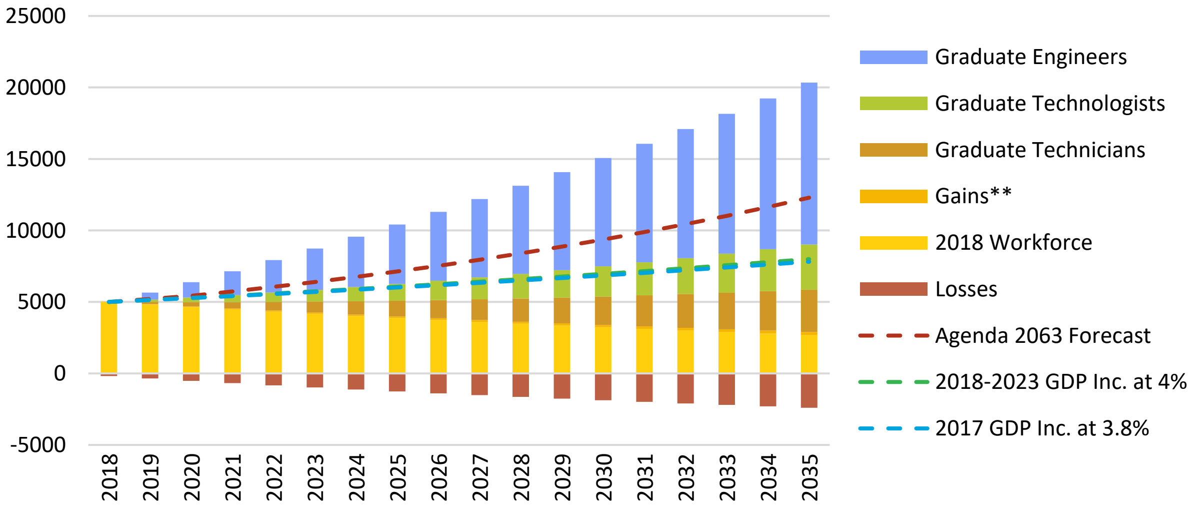


Figure 12: Flow of engineering skills based on a 2% increase in graduation rate per year

**Excludes international engineering practitioners in the country on short-term contracts

*[1] Employment elasticity is a measure of the percentage change in employment associated with a 1% change in economic growth. If the growth is likely to be in agriculture, the percentage could be lower, as growth in that sector generally has to do with productivity gains and not employment, while if the growth is likely to be in high-tech manufacturing, the elasticity factor maybe more than 100%.

demand for each discipline. In terms of the disciplines that require attention, the following is suggested:

- **Agricultural engineering:** There do not seem to be qualifications on offer. However, much work needs to be done in terms of developing further irrigation capacity, mechanisation, post-harvest facilities, etc. Consideration therefore needs to be given to offering bursaries for students to study agricultural engineering out of the country from time to time.
- **Telecommunications:** Given the growth in the sector, encourage more students to study telecommunications locally and consider adding more telecommunications content to the electrical/electronics qualifications.

KEY RECOMMENDATIONS

To develop a sound pool of engineering professionals, able to contribute to the well-being of Mauritius, the following should be considered:

Schooling

- **Mathematics and science:** Strengthen the teaching of mathematics and science to increase the number completing secondary education with acceptable results.
- **Career guidance:** Expand career guidance to attract both genders into the engineering profession.
- **Bursaries:** Provide bursaries to attract those who excel in mathematics and science to study engineering.

Tertiary education

- **Accreditation:** Fund the development of the Engineering Accreditation Board (EAB) to be able to carry out accreditations according to the requirements of the Washington Accord.
    - Fund the extension of the Engineering Accreditation Board's (EAB) capacity to be able to carry out accreditations according to the requirements of the Dublin and Sydney Accords.
    - Encourage institutions to develop adequate complex engineering problem-solving content and graduate attributes to satisfy the requirements of the Accords.
    - Withdraw qualifications which do not meet accreditation requirements.
- **Industry liaison:** Liaise with industry on a regular basis to ensure that curricula, methods, software and equipment are relevant and up to date.
- **Curricula:** Provide funding to research, modernise or develop curricula and material where required.
- **Facilities:** Raise funding to upgrade lecture theatres, libraries and laboratory facilities where required.
- **Resources:** Raise funding for computers, engineering software, access to online reference material, and laboratory equipment, and ensure adequate support to offer technology-relevant training.
- **Attract and retain academics:** Improve conditions of service, support and packages to attract, retain and appoint additional academics.
- **Academic development:** Provide funding for lecturer post-graduate development and facilitate opportunities for academics to gain experience in industry.

Graduate training

- **YEP:** Encourage all employers to participate in the YEP programme.
- **Training guidelines:** Develop comprehensive training plans and mentoring guidelines.
- **Public sector support:** Ensure that graduates trained through the YEP are absorbed and developed through the ranks.
- **Institutional support:** Institutionalise graduate training in all organisations by setting KPIs for experienced staff to act as supervisors and mentors.
- **Project support:** Make graduate training a requirement of all public sector projects and ensure that the progress of graduates is monitored, and penalties are imposed for non-compliance.

Registration of engineering professionals

- **Registration categories:** Consider introducing registration of engineering technicians and technologists.

Continuing development

- **CPD:** Support the participation of engineering practitioners in CPD activities.
- **Validation:** Validate short courses and skills programmes for a specified period only to ensure that training remains up to date and relevant.
- **Post-graduate studies:** Provide post-graduate bursaries to develop specialists.
- **Develop managers and leaders:** Encourage the industry to continue investing in graduates after professional registration to grow management and leadership capabilities.

Registration of service providers

- **Legislation:** The CIDB to consider expanding or enforcing the construction legislation to:
  - Make increasing use of local consultants, contractors, labour, plant and materials.
  - Ensure that there is a requirement for consultants and contractors to train graduates, artisans and other construction-related skills.
  - Ensure that international consultants provide all calculations, drawings, operating manuals and other reference material in English.
  - Ensure that local consultants, along with the client, check that design proposals address local needs and customs and that design calculations comply with national codes and standards.
- **Quality:** Implement quality assurance and ensure penalties are imposed for poor performance.

The public sector

- **Maintenance:** Invest in maintenance to preserve infrastructure and prevent further deterioration of existing infrastructure.
- **Technical capacity:** Reprioritise budgets to fill vacant posts and build technical capacity, ensure that salaries are competitive and develop succession plans to make the public sector an employer of choice.
- **Codes and standards:** Develop local engineering codes and standards for the design of engineering infrastructure where required.
- **Technical decision-makers:** Ensure that engineers are employed in senior decision-making posts.

Industry-wide collaboration

- **Advisory team:** Set up an engineering advisory team, recognised by government, to advise on and endorse infrastructure development proposals, tertiary curricula and graduate training programmes.
- **Collaboration:** Encourage all professional bodies to work together to share knowledge, exchange best practice and ensure coordinated planning of industry support initiatives.

ACKNOWLEDGEMENTS

The detailed picture presented would not have been possible without the help of the various professional bodies, government departments and many passionate engineers. A big thank you to Jagadish Soobarah, Chair of the EAB, for all the contacts and insights; Daliah Deven, President of the CRPE, Dhondee Donald and Raj Prayag, Vice President and President of the IEM, for contacts and setting up professional body meetings, and Navind Ujoodha, Director of the CRPE, for accepting the focal point role, and to Geraldine Adolphe, secretary of the CRPE, for finalising all the logistics and arranging meetings with the government and academia. Thank you to Ram Bahadoor, Executive Director of the CIDB, for lots of data and ideas, and to the many passionate academics and staff at the TEC for sharing ideas and graduation data. Thank you to everyone who participated in meetings and who took the time to travel to meetings, who were well prepared and provided data and insights, as well as to those who responded so diligently to follow-up queries.

SOURCES OF INFORMATION

Data and information were gathered during meetings and interviews, and via email. SADC reports, master plans and strategies as listed under *Plans and Strategies,* and many standard international sets of data as listed in Chapter 5, *Research Approach,* were also consulted. Further information was gathered from news articles and from Labour Force Surveys. The website of the Government of Mauritius contains information on each department and senior personnel, and the website of the Ministry of Finance publishes all capital projects planned and detailed budgets per ministry – both these websites were very helpful. Comprehensive documents focusing on specific issues in Mauritius as listed below were invaluable sources of information.

CIDB (Construction Industry Development Board). 2012. *A strategy paper for the construction industry*. Port Louis.

CMM (Competition Commission of Mauritius). 2018. *Market study of the construction industry in Mauritius*. Port Louis.

Economic Development Board. *Details on various sectors, strategic planning, etc. in Mauritius.* Available at: www.edbmauritius.org/opportunities

HRDC (Human Resource Development Council, Mauritius Ministry of Education and Human Resources). 2012. *A study on labour shortage in the ICT/BPO sector in Mauritius*. Ebène.

HRDC. 2012. *A study on labour shortage in the manufacturing sector in Mauritius*. Ebène.

IEM (Institution of Engineers Mauritius). 2017. Report on a pilot project on building engineering capacity through the accreditation of engineering degree programmes. Quatre Bornes.

International Trade Centre. *Country Paper – Mauritius*. Available at: www.intracen.org/WorkArea/DownloadAsset.aspx?id=53113 [Accessed on 16 December 2017].

Kumar, B.N. 2012. The Impact of nine-year schooling on higher learning in Mauritius. *European Scientific Journal,* August 2012, Special Edition. MCCI (Mauritius Chamber of Commerce and Industry). 2012. *DOE Manufacturing – What strategy for a new generation of growth?* Ebène.

PRB (Pay Research Bureau, Prime Minister's Office, Mauritius). 2016. *Review of pay and grading structures and conditions of service in the public sector.* Port Louis.

Statistics Mauritius. 2013. 2013 Census of Economic Activities: Phase I – Small Establishments. Port Louis.

Statistics Mauritius. 2013. 2013 Census of Economic Activities: Phase II – Large Establishments. Port Louis.

Statistics Mauritius. 2014. 2014. Census of Agriculture. Port Louis.

MOZAMBIQUE

MOZAMBIQUE lies on the east coast of southern Africa. It shares borders with six other countries: Tanzania, Malawi and Zambia to the north, Zimbabwe to the west, and South Africa and Eswatini to the south. Beira in Mozambique represents an important trade port for the landlocked countries of Malawi, Zambia, Zimbabwe and Eswatini.

In recent years there has been substantial economic growth due to increased coal and gas production and manufacturing activity. The economy has deteriorated since early 2016, following the revelation of undisclosed borrowings.

Despite economic activities, Mozambique is still one of the world's poorest countries, in which most of the rural population lacks basic services such as access to safe drinking water, health facilities and schools. Almost 63% of the population lives below the international poverty line.

Unemployment is widespread, particularly among the youth, almost 45% of whom are under the age of 15 years. In 2016 unemployment was estimated to be 24.4% and in 2017, HIV/AIDS prevalence was rated as the seventh highest in the world at an estimated 7.3%.

The capital is Maputo, which is also the largest city. Approximately 32% of the population lives in urban areas, spread across 53 municipalities. Roughly 90% of a typical town or city is made up of poorly serviced informal settlements and with continuing urbanisation, cities are becoming denser, particularly in unplanned settlements.

THE ECONOMY

Although the engineering activities are major contributors to the GDP, they contribute over 55%, with finance, services, wholesale, retail, trade and other activities making up the balance.

The debt revelation of 2016 resulted in a slowdown in growth and shocks to the country's currency and to inflation. Inflation reached 25% in 2016 and the lending rate is among the highest in sub-Saharan Africa, making access to funds prohibitive for much of the private sector.

A substantial trade imbalance persists and without progress in the debt-restructuring process, the country's debt position remains untenable, limiting the opportunities for investment and development.

Strengthening prices for coal, aluminium and gas will improve the trade balance to some extent, but robust fiscal policy and control are necessary.

PLANS AND STRATEGIES

There are several important plans and development policies in place, the most important of which are:

- **Agenda 2025** which highlights medium- to long-term priorities in terms of governance, human capital and economic development, and focuses on productivity increases and attracting investment in agriculture and fisheries.
- **National Development Strategy (ENDE) (2015–2035)** which is a national vision for economic and social development, which focuses on industrialisation, by growing the extractive sector, among others. Important activities include the development of human capital,

Table 1: Mozambique metrics

Population	
Total	28 862 000
Urban	31.8%
Rural	68.2%
Poverty, HIV, Unemployment	
Below the international poverty line	62.9%
HIV-positive	7.3%
Unemployment	24.5%
Human Development Index	0.416
Electricity	
Production kWh	18.39bn
Consumption kWh	11.57bn
Airports and Ports	
Airports	98
- Paved	21
- Unpaved	77
Ports (major seaports)	7
Kilometres of Services	
Roads	31 083
- Paved	7 365
- Unpaved	23 718
Rail	4 787
Pipelines	1 250
- Gas	972
- Refined products	278
Waterways	460
Africa Infrastructure Development Index	12.49
Access to Services	
Access to safe drinking water	51%
- Urban	83%
- Rural	37%
Access to improved sanitation	27%
- Urban	58%
- Rural	13%
Access to electricity	39%
- Urban	66%
- Rural	27%
Telephones	82 421
Mobile phones	15 025 598
Internet users	18%

infrastructure, research and innovation, and strengthening institutions.

- **The National Energy Strategy (2014–2023)** which aims to increase access to diverse forms of energy, contributing to the welfare of the population and socio-economic development through increased production, transmission and distribution of electricity, and fuel production, improving access to finance and addressing pricing and capacity development.
- **Electricity Master Plan (2012–2027)** which aims to achieve electrification of 44% by 2021, improve the quality of supply in main cities, industrial and expansion areas, and reduce losses to 18%.
- **National Programme for Rural Water Supply and Sanitation (PRONASAR) (2010–2015)** which aims to guarantee sustainable access to improved rural water supply for at least 65% of the rural population by 2015 and improved sanitation for at least 25%.
- **Strategic Plan for Agricultural Development (PEDSA) (2010–2019)** which aims to grow agricultural productivity, particularly in the smallholder sector, by offering extension support, research input, improved infrastructure including irrigation, marketing support and ensuring that resources are used in a sustainable manner.
- **National Irrigation Strategy (2011–2019)** which plans to double the total irrigated land in the provinces of Sofala, Manica and Zambézia from 66 000 ha to 113 000 ha by 2019.

ENGINEERING ACTIVITIES

Figure 1 shows the contribution of engineering-related economic activities to the country's GDP. The largest sector is agriculture, followed by transport and communication, and manufacturing. Considering each in turn will give a picture of the activities, trends, challenges and opportunities for the engineering profession to contribute to Mozambique's growth.

AGRICULTURE

Tobacco, sugar, sesame seeds, cotton and cashew nuts are flagship agricultural exports, which made up about 20% of total exports in 2014. Maize, rice and cassava are the most important food crops. Agriculture is the single largest employment sector, employing around 73% of the labour force in 2016.

Subsistence farming

There are approximately 3.7 million farms, most of which are small family holdings of around 1.2 ha. Smallholders account for most of the food produced and contribute 25% of GDP. Productivity is low, as a result of a loss of know-how due to HIV/AIDS, deterioration of seed, fertilisers and methods, and limited use of modern technology. Although smallholder irrigation exists throughout the country, it has either been abandoned or is underutilised. Most schemes are in a bad to very bad condition, due to destruction during the civil war or the floods of 2000 and 2001.

New smallholder owners lack experience in the operation and maintenance of irrigation schemes and do not get support as public funds have been withdrawn for irrigation.

Lack of capital and skills to design and build dams and irrigation systems, and roads to connect farmers to markets, means that production is limited to family consumption, which can also be compromised during drought conditions.

Commercial farming

In 2016, it was reported that there were some 130 large farms (greater than 50 ha) in Mozambique. These tend to be located in wealthier and better educated areas, with higher levels of population

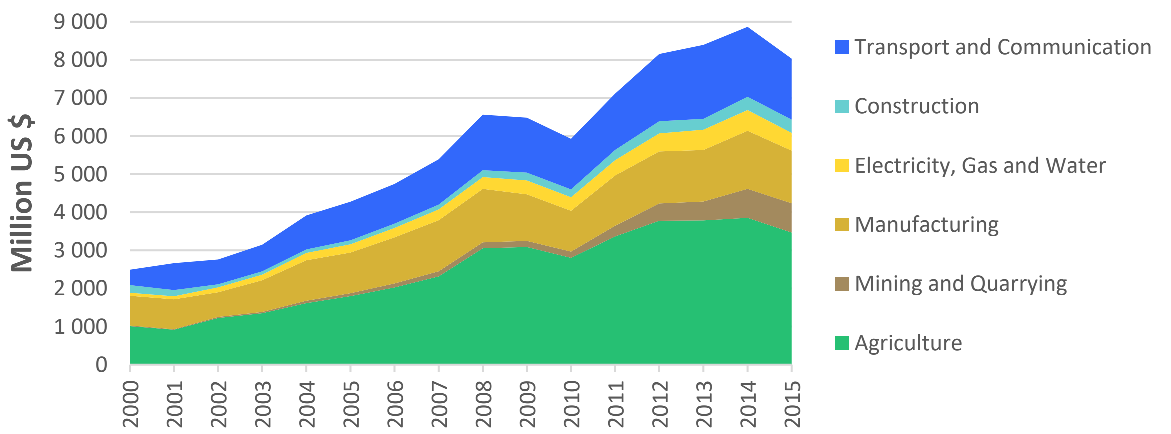


Figure 1: GPD per engineering-related economic activity (57% of the GDP)

MOZAMBIQUE

density. They would typically be found in peri-urban areas where they can access a more knowledgeable and plentiful labour force, a larger and wealthier potential market for their produce, and better transport connections.

Crop and post-harvest losses are experienced by farmers, with as much as 30–40% of crops being lost in the value chain. Considerable investment is needed in the sector, including irrigation, hatcheries, slaughterhouses, food storage, processing and logistics, to contribute more effectively to economic growth.

Forestry

The forest sector is divided into two main sectors: formal forest industries and informal or subsistence forest enterprises. Both sectors are engaged in the production of timber products, non-timber forest products and the provision of forest-based services such as eco-tourism, conservation of biodiversity and carbon sequestration.

The main bottlenecks in operational efficiency include the location of the forests and associated transport costs, poor road conditions and inadequate vehicles. Forest roads should be part of a well-planned rural road network. Small dams are also considered necessary to increase resilience to extreme drought conditions, but technical expertise is required to ensure compliance with Dam Safety Policy requirements.

To increase the economic contribution and sustainability of forests, a 20-year forest vision and a National Forest Programme have been prepared. This will improve forest management and the use of modern methods and technologies.

MINING AND QUARRYING

Mozambique has vast reserves of high-quality coking and thermal coal, graphite, iron ore, titanium, apatite, marble, bentonite, bauxite, kaolin, copper, gold, tantalum and natural gas. In world terms, as per 2010 reports, the country produced 16% of the world's tantalum, 6% of the ilmenite and 3% of the zircon. In 2017 heavy mineral sands contributed 4.4% to the total exports.

Also in 2017, coal became the country's number one export, representing 30.4% of exports, displacing aluminium at 25.5%, while natural gas contributed 7.4% to exports.

Many important mining developments and expansions are taking place, which indicate the need for a vast increase in capacity in mining engineering and metallurgy.

- **Coal:** Large scale mining has commenced in the past five years. Production at Vale's Moatize coal operation was expected to reach 13 million tons by 2018, which has been made possible by major infrastructure developments, including a second coal handling and processing plant, and the inauguration of the railway line to the coal terminal at the Port of Nacala. The railway line can carry 18 million tons of cargo a year.
- **Gold:** Production is forecast to grow by 1.1% annually from 2016 to 2020 and exploration in alluvial sands is underway.
- **Graphite:** Additional mines have come on stream to tap into graphite reserves – Ancuabe started in 2017, with a capacity of 9 000 tpa, and Balama in 2018, with a capacity of 380 000 tpa.
- **Iron and steel:** Iron ore mining has resumed with improved prices, and there are plans to develop a pig iron project in Tete Province to supply iron and steel for regional infrastructure projects.

Many multinational companies are engaged in prospecting, research and development, while others are in the production phase. It was estimated that there were more than 150 projects in the mineral resources and hydrocarbons sector in 2014.

MANUFACTURING

The main products manufactured are food, beverages, aluminium products, petroleum products, textiles, cement, glass and tobacco. The broad industry sectors are shown in Figure 2. Almost all manufacturing takes place in the major urban areas of Maputo, Beira and Nampula. Industrial priorities identified by the National Directorate of Industry in 2015 are the development of the food, furniture, materials for construction, mechanical, electrotechnical and chemical industries. The collection and recycling of

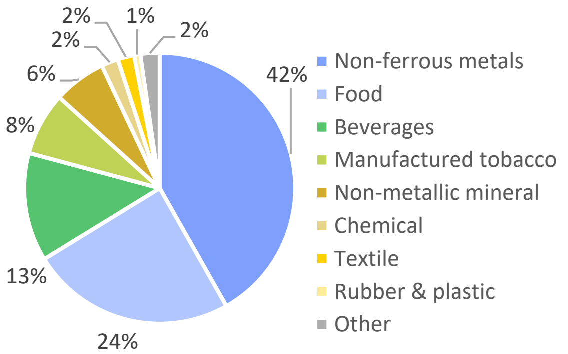


Figure 2: Manufacturing value add per subsector, 2013

industrial waste and the effective use of natural gas for energy were also considered important.

Food, beverages and tobacco products

The agri-business and food-processing sector comprises sugar manufacturing (with four mills producing more than 380 000 tons per year), processing of fruit and vegetables, and the production of edible oils from cotton, coconut, sunflower, groundnuts and sesame. Grain milling and associated bakery products, seed, milk and dairy products, and intensive poultry production are also important.

The beverage industry comprises a major local beer producer, a producer of wines and spirits, three companies producing bottled water and many small informal enterprises, which make traditional alcoholic drinks. The Heineken Group expects to start producing beer in Mozambique from the first half of 2019 in a factory with a production capacity of 80 000 hectolitres (hℓ) per year.

Tobacco is one of the most important agricultural export crops and one of the major sources of income for 129 755 farmers; it represents about 34% of total agricultural exports and almost 4% of total exports of goods and services. There are several manufacturers that process, pack and supply flue-cured and burley tobacco products.

In terms of cotton processing, the bulk of the output is in food and animal feed production.

Textiles and clothing

The textile industry in Mozambique started with the production of natural fibres, including cotton and sisal, mainly for export. In June 2015, there were 15 operational ginning companies, 12 cotton pressing plants, one dyeing company and only one spinning and weaving company. Most of these plants require some engineering capacity to operate, or at least give advice on maintenance.

Today the domestic market is flooded with second-hand clothing and *capulana* (wraparound fabrics of African prints).

Several local clothing manufacturers produce woven and knitted clothing, using imported fabric. Expansion of this industry is limited due to the lack of available empty buildings or factory shells, and companies complain that the costs of electricity, water and transport are high by comparison with neighbouring states, making them uncompetitive.

Timber, pulp, paper and packaging

The forestry sector accounts for some 10% of industrial production and contributes around 1% to the GDP. Products include sawn timber, railway sleepers, wooden poles, wooden flooring, furniture, and door and window frames. Deforestation is of concern due to the use of wood for domestic use. Major campaigns are underway to increase the efficiency of charcoal-making and to introduce alternative cooking and energy technologies.

In 2011, a permit was granted to develop up to 356 000 ha of forests and a mill to process eucalyptus into paper pulp. The mill, which is expected to produce 1.5 Mt, and a biomass power generation plant should be operational by 2023.

Plastics, chemicals and other non-metallic mineral products

The are many plastic manufacturers with numerous plants, producing both raw materials and a range of products, including coated electric wires and cables, PVC and HDPE products, PET bottles, plastic boots, household products, industrial crates and tanks, plastic films and bags, to name a few. Although there are major producers processing thousands of tons of raw materials per year, many companies in the sector operate with a few plastic-moulding machines. The opportunities to grow the sector and introduce advanced technologies are considered to be limited due to a lack of local skilled personnel and the lack of training institutions to develop professionals in this sector.

The main chemicals produced are paints, glues, varnishes, detergents, foams, cosmetics and industrial gases.

Several new cement factories were developed in 2015 to reduce Mozambique's reliance on imported materials, as Mozambique has abundant deposits of limestone. In 2014, there were four cement firms in operation, one of which, Cimentos de Moçambique, accounted for three-quarters of total sales and operates three factories. The new plants were expected to increase local production from 2 million to 5.3 million tons. However, due to the depressed economic climate and reduced demand, plants were operating below capacity in 2018.

Pharmaceuticals

Pharmaceuticals are largely imported generics with only one pharmaceutical company in place, which was established in 2012 and makes large-volume injections, antiretroviral drugs and various basic medications in tablet and capsule form.

Metal industries, machinery and equipment

The metals, engineering and assembly area comprises aluminium and steel production, the manufacture of wire and sheeting for the construction industry, the production of metal furniture and electrical cables, and vehicle body building. Manufacturing is dominated by the Mozal aluminium smelting plant.

Recent major investments in the sector include Hyundai's investment in a car assembly plant and Matchedje Motor's joint venture between the government and China Tong Jian Investment Co to produce its own locally made vehicles.

ELECTRICITY, GAS AND WATER

Electricity

Seventy-eight per cent of Mozambique's energy supply is generated from biomass, 14% from hydropower, while natural gas, petroleum and coal make up the remaining 8%. Energy supply is derived from both domestic and international sources. Mozambique’s generation capacity exceeds local consumption, but transmission lines have been developed as three separate systems with limited interconnection, which means that large areas do not receive electricity. Due to the undeveloped distribution network, only 39% of the population had access to electricity, made up of 66% of the urban population, and 27% of the rural population in 2013.

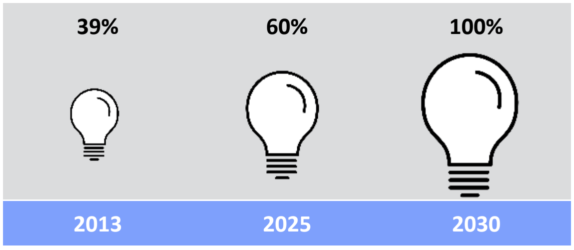


Figure 3: Target dates for access to electricity

Electricidade de Moçambique (EDM) is the public utility responsible for distributing all electricity in the country. A separate company, Hidroeléctrica de Cahora Bassa (HCB), has been set up to manage generation from Cahora Bassa. Cahora Bassa is the biggest hydroelectricity producer in the country and the largest regional generator. Some 90% of its output is exported to South Africa, while 30% of that amount is re-imported through South African transmission lines and entirely consumed by the Mozal aluminium smelter. Electricity is also exported to Zimbabwe.

The large distances between generation and consumption, dependency on single lines, as well as large parts of the country that are not covered, are major challenges for electricity supply and electrification. In response, the government plans to expand generation capacity to 3 138 MW by 2022 and 4 163 MW by 2030. This will be made up of around 3 000 MW hydropower and 1 400 MW from natural gas, among other sources. In this scenario, Independent Power Producers (IPPs) will become the largest group of generators. At present IPPs sell through EDM, but the legislation is under review. Although no coal power plant has been constructed to date, the country has approximately 2 GW of coal capacity and a generation plant to tap this resource is also being planned.

There are several other possible sources of energy, including solar and wind potential. Construction of the first large-scale solar plant, a 40.5 MW solar PV plant in Mocuba, started in early 2018. The plant will deliver power to the national grid and produce energy for some 175 000 households. Off-grid solutions will include diesel generation and solar generation for remote households and irrigation.

The transmission grid will be expanded from the north to the capital Maputo, via the development of a backbone which will create a grid to service the country's major consumption zones and connect it to the South African market.

Oil and gas

The distribution and marketing of fuel products and lubricants is carried out by Petromoc (state owned) and BP, Mobil and Caltex, while Empresa Nacional de Hidrocarbonetos de Moçambique (ENH) has sole rights to explore for and develop petroleum. Biofuel exploration is being undertaken by the Brazilian company Arranjo Produtivo Local do Alcool (APLA) for export purposes to Brazil.

In late 2009, the discovery of liquefied natural gas (LNG) looked set to change the economy. With 75 trillion cubic feet (Tcf) of recoverable natural gas having been discovered in the offshore exploration Area 1 and national potential reserves of up to 200 Tcf, the discovery is expected to yield 2.3 billion cubic feet per day (Bcfpd) by 2023, to feed into local gas terminals, small domestic consumption and gas exports to South Africa. Once gas production reaches its peak growth, Mozambique is expected to become the third-largest LNG exporter in the world after Qatar and Australia.

By the end of 2018, Sasol (South Africa) was producing natural gas in a facility in Temane. This is transported via an 865 km pipeline to the Sasol plant in Secunda, South Africa, to support the production of chemicals and as a substitute for the gas produced from coal. A link to southern Mozambique has also been developed. Sasol plans to develop an integrated oil and liquefied petroleum gas facility adjacent to its existing petroleum facility. Several other oil companies are planning to develop LNG plants and distribution systems in the coming years.

The Mozambican National Petroleum Institute (INP) has awarded gas-development projects to three organisations: Yara International which will develop fertilisers and 30–50 MW of power; Shell Mozambique which will produce diesel and 50–80 MW of power; and GL Energy Africa which will produce 250 MW of power. The first gas-driven power stations were opened in Ressano Garcia in 2016 and in Maputo in 2018. The latter will add 25% to the electricity supply for southern Mozambique, increasing the quality and improving the reliability of the electricity supplied to consumers. There is an urgent need to develop or expand existing qualifications to train engineers in this field.

Water and sanitation

Mozambique has many major dams, but several in remote areas were developed for hydroelectric schemes. As a result, in 2015 only 51% of the population had access to safe drinking water, made up of 83% of the urban population and 37% of the rural population. By contrast, only 27% of the population had access to improved sanitation facilities, made up of 58% of the urban population and 13% of the rural population.

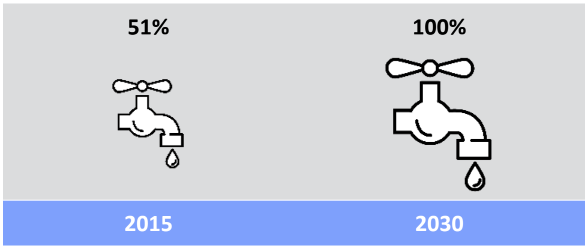


Figure 4: Target date for access to safe drinking water

Around 70% of Mozambique's population uses pit latrines. It is estimated that the lack of improved sanitation costs Mozambique about 4 billion Meticais a year, due to premature deaths, medical costs and losses in productivity.

There are limited wastewater treatment facilities in the country. Maputo was the only city with a central sewerage system for collection and treatment of domestic sewage until 2012, when a plant opened in Beira. Due to lack of maintenance, the treatment

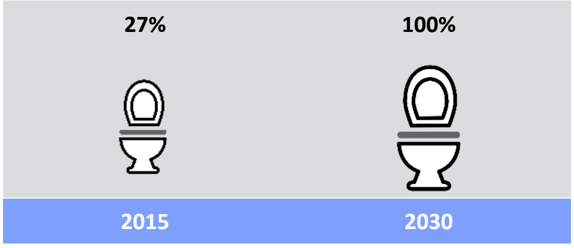


Figure 5: Target date for access to improved sanitation

works in Maputo was not operational for a long period, and thus the sewage and industrial waste is flushed into the Indian Ocean. In the past, households in Maputo would empty their toilets manually and bury faecal sludge in yards. As the city continues to densify, this has become a health hazard and a faecal sludge removal business has been developed to safely empty and transport faeces to treatment plants. Several private operators are now involved with this process, but treatment capacity urgently needs to be expanded.

TRANSPORT AND COMMUNICATION

In terms of geography, Mozambique enjoys a privileged and strategic location as the natural exit to most of its landlocked neighbours, Zimbabwe, Zambia and Malawi. Transport infrastructure connects mining and agricultural clusters inside Mozambique and in neighbouring countries to exit ports. There are three clear road and rail corridors:

- **Maputo Corridor** which links Maputo with the industrialised and productive regions of Gauteng and Mpumalanga provinces in South Africa (and also connects Zimbabwe and Eswatini through the rail network). Upgrades to the rail service and container terminal in Maputo are planned to take freight off the road and speed up the journey time and logistics.
- **Beira Corridor** which links Beira to Zimbabwe. The Machipanda and Tete (to Moatize) rail lines have been developed as part of this corridor and roads have been upgraded.
- **Nacala Corridor** which links the Port of Nacala to Malawi and ultimately to Zambia.

Roads

Mozambique has only 31 083 km of roads. South Africa, a country only one-and-a-half times larger than Mozambique, has a road network more than 11 times greater. Considering the limited network, what is of more concern is that only around 24% of roads are paved, limiting the transport capacity.

Since 2012 significant road development has taken place, developing, upgrading and/or surfacing key routes from Nampula to Cuamba, Beira to

MOZAMBIQUE

Machipanda, Maputo to Ponta do Ouro, Liwonde to Mangochi, and Mueda to Negomano, among others. Many more developments are planned. Of concern is the fact that apart from the north-south National Road N1, the country has limited connection to the several west-east corridors. It was estimated in 2016 that developing full connectivity through upgrading and construction of roads, bridges, railways and airports would require US$11.6 billion.

The Catembe Bridge is possibly the most spectacular development to have taken place since 2014. Costing US$725 million, and spanning 680 m, the bridge is the longest suspension bridge in Africa. It will ease traffic flow in Maputo and will boost activity in the south of Mozambique, as well as facilitating connections with South Africa.

Rail

The rail system is composed of a total of 4 787 km of rail of the 1 067 mm (3 ft 6 in) gauge which is compatible with neighbouring rail systems. A 140 km line of 762 mm (2 ft 6 in) gauge from Xai-Xai, known as the Gaza Railway, is no longer functional.

Portos Caminhos de Ferro de Moçambique (CFM) is the utility responsible for overseeing the railway system and its connected ports. CFM oversees three main east-west lines which connect major centres to ports as follows:

- **Maputo railroad/CFM Sul** which links to Komatipoort in South Africa, Swazi Rail and the National Railways of Zimbabwe
- **Beira railroad/CFM Centro** which connects Beira to Harare
- **Nacala railroad/CFM Norte** which connects the Nacala Development Corridor to the Central East African Railway (CEAR) of Malawi; this was upgraded to include a line from Moatize to Malawi in 2017.

There is no interconnecting rail service between the three lines.

The construction of an additional 639 km from Chitima to Moatize and on to a new floating coal terminal off the coast at Macuse is planned to commence in 2019.

There is recognition that existing lines need rehabilitation and investments are planned to ensure a better quality of service from 2018 onwards, considering both the railway and the metro networks. Plans are also being considered for the construction of a metro line linking the cities of Maputo and Matola.

In terms of rolling stock, new locomotives and carriages were planned to come into service in 2018. In addition, a four-year programme commencing in 2016 was aimed at refurbishing 45 locomotives and reconstructing 670 wagons to join the 300 units already repaired and back in service.

Ports

The major Indian Ocean seaports are Nacala, Beira and Maputo. In addition, there are a number of secondary ports, including Pemba and Quelimane.

Maputo is the largest and busiest port and also serves the Gauteng province in South Africa. A major dredging project in 2016 increased the draft from 11 m to 14.5 m and with an increase in container capacity, the port has seen increased traffic – handling 18.2 m tons in 2017.

Beira is the second-largest port, which serves the coalfields utilising the Sena Railway. To accommodate more freight, the coal terminal is to be upgraded and dredging is planned to increase the draft from 8 m to 9.2 m.

Nacala is the third-largest port and is said to be the finest natural deep-water harbour in Africa, with a large and sheltered bay up to 60 m deep and an

Disclaimer:
Aurecon gives no warranty of any kind, expressed or implied, with regard to the map or data whether for its reliability, accuracy or completeness and shall not be held liable in any event for any loss or damage in connection with or arising out of the use of this data or map. The Client accepts all inherent limitations of the maps and data, including the fact that the maps and data are dynamic and in a constant state of maintenance, correction and revision. The data and map remain the sole property of the CLIENT and may be used for purposes of this Project with the prior written approval from the CLIENT. aurecon

Figure 6: Transport corridors

Figure 7: Catembe Bridge construction in 2017 – completed 2018
(Photographer: Lawrence Greene)

entrance that is 800 m wide. To take advantage of this, modernisation and expansion works are planned to reconstruct and expand the pier, acquire general-cargo handling equipment, construct a railway container terminal and improve access roads.

To increase coal exports a new port, the Macuse Port is being considered. The port will be able to receive ships of up to 80 000 tons – much larger than the ships that can dock at Beira, although Nacala has the advantage that it is so deep that it can take ships of any size.

Airports

Aeroportos de Moçambique company manages 20 airports nationwide, of which six are international.

Linhas Aéreas de Moçambique (LAM) is working on a five-year action plan that provides for the reopening of routes to Europe and the creation of new scheduled flights to South America and Asia from Nacala Airport, which is in the north of the country. The development of Nacala is justified since several industries have been established in the north, along with tourism. The opening of these lines depends on the provision of aircraft of greater capacity. A recent upgrade to Maputo International Airport increased the capacity from one million to five million passengers a year, as it can now accommodate the largest of aircraft, such as the Airbus 380.

Communications

The telecommunications sector is fast-growing but is still underdeveloped. As of 2016, there were 15 million mobile device subscriptions, representing a 52% penetration rate. Two operators, mCel (which is state owned) and VM, have been in operation for more than 10 years, but to create more competition and reduce pricing, an additional operator, Movitel, was introduced. The fibre optic network covers 11 provincial capitals, 52 districts and 31 stations, but activity generally follows the population and is found in the south-central and southern areas.

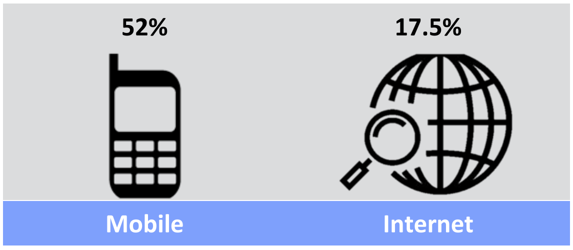


Figure 8: Percentage of population connected to services

Fixed-line services are provided by Telecomunicações de Moçambique, SA (TDM). As of 2016, there were 82 421 fixed-line subscriptions, representing a 0.29% penetration rate. In addition to voice transmission, TDM also offers internet connectivity. However, due to the poor fixed-line infrastructure, the fixed-line internet market is limited and mobile internet accounts for most connections. Around 17.5% of the population are internet users.

Migration from analogue to digital broadcasting in Mozambique commenced in 2009. In this process, Digital Terrestrial Television was launched, and TMT SA was set up to take responsibility for transmission, multiplexing and distribution of the digital broadcasting signal. Current telecommunication infrastructure includes:

- A national transmission system (backbone) and switching systems of TDM, mCel, VM and Movitel
- Regional and international transmission infrastructure which includes SEACOM submarine connectivity to the rest of Africa,

Europe, Asia and the Middle East, and EASSy regional submarine cable.

Despite the growth of smart devices and internet access, there are still some areas that are cut off from the virtual world. Mozambican technology startup company Kamaleon is bringing internet access to remote rural areas through a platform called 'Community Tablet' (Tablet Comunitário). The Community Tablet aims to promote digital inclusion and ensure that more people have access to information and communication technologies. It is an effective solution for schools, health departments and hospitals for developing and broadcasting health education and other messages to the community, as opposed to distributing leaflets with information. There are plans to expand the Community Tablet into other Africa countries.

CONSTRUCTION

Construction is important in any country due to its ability to create jobs and develop skills. The majority of foreign companies report shortages of technical skills and key inputs due to the limitations of the Mozambican industrial base. The key input requirements along the construction value chain consist of construction materials (i.e. cement, concrete products, aggregates, reinforcing and structural steel) and machinery and equipment supplies (particularly earthmoving equipment). All materials aside from cement (which is locally produced) are imported through local distributors or directly from South Africa and other cheaper sources (i.e. India, China and Pakistan).

The procurement environment favours foreign multinational companies which use strategies such as competitive pricing, strong coordination of the supply chain and establishing strong relationships with clients to boost their chances for repeat work.

Table 2 lists some of the major infrastructure projects planned or under construction – with power generation, oil and gas infrastructure, and port expansions being the most substantial developments. Mozambique has adopted the approach of concessioning major projects. Concessionaires have no difficulty in conceptualising and designing solutions, but developing bankable projects presents a problem, and many have faltered due to the inability to raise funds. The status of each project is shown in the table, annotated as follows:

- **P:** Potential project
- **P/F:** Project concessioned and pre-feasibility or feasibility underway
- **F:** Project concessioned, but concessionaire has, to date, failed to raise funding
- **C:** Project under construction.

Once the large natural gas projects are approved in the north of the country, the infrastructure sector is expected to dominate economic growth in the medium term. This sector is dominated by Portuguese, Brazilian, Chinese and South African construction firms, with Turkish, Japanese and Italian companies recently entering the market. Engineering Procurement Construction (EPC) contractors from the USA have also started to enter the market, with CB&I's participation in the joint venture that won the EPC contract to build Anadarko's onshore LNG park.

Residential and commercial construction is important in the major centres. Since 2010 Maputo's skyline has been changing, with new towers and commercial

Table 2: Major projects identified, or being planned or under construction

PROJECT		STATUS	VALUE US$	START YEAR	END YEAR
Energy	1 250 MW Cahora Bassa Norte Hydroelectric Dam	P	$700m	Planning	
	1 500 MW Mphanda Nkuwa Hydroelectric Dam	P/F	$4.2bn	Feasibility	
	210 MW Boroma Hydroelectric Dam	P	$572m	Feasibility	
	416 MW Lupata Hydroelectric Dam	P	$1.1bn	Seeking funding	
	180 MW Lúrio Hydroelectric Dam	P	$480m	Seeking funding	
	CESUL high-voltage power lines	P/F	$2bn	Feasibility	
	Mozambique–Zambia interconnector	P	Feasibility		
	Zimbabwe–Mozambique interconnector	P	Pre-feasibility		
Gas	Area 1 LNG park including of offshore gas platforms, LNG terminal, downstream power and chemicals plants, base facilities and community resettlement		$30bn	Commenced and ongoing	
Ports	Maputo Port expansion/modernisation	P/F	$750m	Feasibility	
	Nacala Port expansion	P/F	$285m		2020
	Macuse Port development	F	$810	2019	2023
Rail	Beira-Machipanda railway upgrade		$400m	Seeking funding	
	Moatize-Macuse railway development	F	$1.9bn	2019	2023

complexes being announced regularly. These projects are developed and financed by the local private sector as well as foreign real estate investors.

Housing

The demand for housing far outstrips supply in the middle- and low-income market. Low-income households are largely excluded from the formal housing market and have no choice but to rely on auto-constructed, informal options. The Fund for Housing Promotion (FFH) estimates a housing deficit of two million units, affecting over 13.5 million people.

The equivalent of 2.5 million families, or 60% of the population, live in substandard housing and approximately 70% of the households in Maputo live in informal housing. There is very limited investment in the low-cost housing sector as investors prefer high-end projects.

Potential developers are also put off by the need to build supporting transport and services infrastructure for new sites and the lack of government support for low-cost housing schemes. Plots are often far from main roads and not linked to the public water and electricity network.

The state owns all land in Mozambique and land rights may not be sold, mortgaged or otherwise alienated. The Land Law recognises a 'use right to land' (*duat* in Portuguese) and any investment made on the land itself is private property and can be bought, sold or mortgaged. The registration and cadastre systems only cover limited urban areas.

Ambitious targets have been set by the Mozambican government to build about 100 000 houses across the country, from 2018 to 2019, for low-income families. This is part of a government initiative called Integrated Programme for Construction of Social Housing.

Mortgage interest rates are high at around 28% and a minimum down payment of 20% is required. Newly built condominiums have increased the availability of housing in higher income markets. However, these cost some 30% more than equivalent developments in South Africa due to higher material costs, low labour productivity and high financing costs. Most materials are imported from South Africa, Portugal and China, and only the most basic materials such as cement and wood are sourced locally.

LOCAL GOVERNMENT

There are 11 provinces in Mozambique. Ten provinces are divided into 154 districts, while the eleventh, the capital Maputo, has been given provincial status. Local government is made up of 53 municipalities and 154 districts. Municipalities are autonomous, funded through rates and payment for services. Districts are managed and funded by the state, but generally only receive a portion of the funds for which they apply. Services are limited and/or require maintenance. This impedes the development of businesses, particularly agro-processing in rural areas.

Electricity is provided to consumers throughout the country by EDM. The government has committed to providing electricity to the capitals of all districts by the end of 2018. Most electricity is supplied through a prepaid system known as CREDELEC. When buying electricity, users are also charged levies for waste removal and radio taxes. Some of these levies make their way back to the districts. With an increased number of users, it is hoped that district budgets will increase.

In municipalities, water is provided by Aguas de Moçambique (ADM), while in the districts, water is largely provided by boreholes and from surface water.

With regard to all the other services, municipalities and districts are expected to develop, manage and maintain surfaced and gravel roads, wastewater treatment works, street and traffic lights, municipal amenities, parks and cemeteries, and to handle building control and waste management. For this a range of engineering skills is required, along with an adequate fleet of vehicles.

There is a shortage of engineering skills in local government, particularly in the district structures, due to their limited income.

EDUCATION, TRAINING AND PROFESSIONAL DEVELOPMENT

Education and training is a vital part of developing engineering capacity. All elements, from teaching appropriate subjects at schools, to continuing professional development (CPD), need to be in place to educate, train and ensure that engineering personnel remain abreast of the latest technology, challenges and emerging solutions.

PRIMARY AND SECONDARY EDUCATION

Primary education spans seven years and secondary education is broken up into three years, termed 'middle education', followed by a final two years.

Due to years of war and the destruction of almost half the schools in Mozambique, education has suffered greatly. Less than 40% of Mozambique's youth get to high school, as can be seen in Figure 9, only 7% attend the final two years of school and even fewer go to

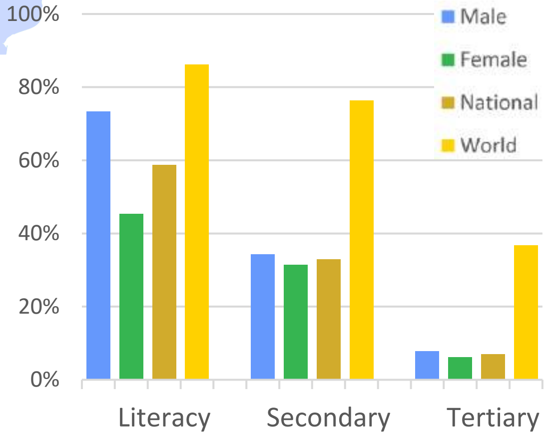


Figure 9: Literacy and enrolment statistics

(UNESCO from 2015 to 2016)

university. Education suffers many challenges, including high learner-to-teacher ratios, limited access to books and learning materials, inadequate classroom facilities, and lack of adequately trained teachers. To increase the number of teachers, unqualified teachers have been appointed. As a result, it is reported that many who do complete school still cannot read and write Portuguese. Just over 100 000 complete high school education each year.

VOCATIONAL EDUCATION

It is also possible after middle education to complete a further three years in vocational education at a TVET college, training to become what is termed a 'mid-level engineer' – these are typically supervisors of operators or artisans who have completed their technical training in the final two years of secondary education at TVET colleges. The final qualifications following either route are considered to be at the same level. Passing either qualifies learners to enter university.

HIGHER EDUCATION

In 1992 there were only three higher education institutions, one of which, the Universidade Eduardo Mondlane (UEM), offered engineering qualifications. The number has since increased to 48 with 19 institutions offering the five-year *licenciatura* (engineer) qualification, as shown in Table 3. Others have commenced offering a three-year *bacharelato* but graduates are not recognised by the Ordem dos Engenheiros de Moçambique (OrdEM). The UEM commenced offering an oil and gas qualification in 2013 and enrolled 51 students. They would not have graduated by 2015, hence NQ for None qualified, in the table. With the rapid development of institutions and increase in student numbers, research and teaching standards remain low. In 2014, 123 800 students were enrolled in higher education, but only 24% of their teachers held a master's degree.

In April 2015, the World Bank approved US$45 million for the Mozambique Higher Education Science and Technology Project, aimed at building capacity in technical and vocational education and expanding research.

Very few Mozambicans enrol in universities and receive university degrees – creating only a small pool of locals to fill key technical and managerial positions in government and the private sector. This has prevented the local private sector from meeting the stringent standards required of industry and contracting to employ local skills as part of contracts.

The Partnership for Skills in Applied Sciences, Engineering and Technology (PASET) aims to help increase access to higher education in STEM subjects. The graduation statistics per institution are shown in Figure 10 and the split by gender and discipline is shown in Figure 11. Technician and technologist qualifications at NQF levels 6 and 7 as defined for this study do not appear to be offered in Mozambique. The report therefore looks at the supply of and demand for engineers with professional degrees only.

It can be seen that graduations from UEM are still dominant in the engineering field. The proliferation of institutions offering engineering qualifications is of grave concern. Many classes are small, and institutions cannot afford to provide an adequate range of academics, laboratories or equipment to offer quality education. A consolidation of institutions offering engineering qualifications is urgently needed.

One of the private universities, Instituto Superior de Transportes e Comunicações (ISUTC), has been innovative in its teaching approach. Given the vast upgrades required to the rail network in the country and further afield, it has developed a railway engineering qualification, with the first students graduating in 2014. The qualification includes civil engineering to address perway design, electrical and electronics courses to address electrification, and signalling and mechanical courses to address rolling stock specification and maintenance.

As this qualification is relevant for most of the countries in the region, which need to upgrade their ageing infrastructure or develop link lines, ISUTC is planning to start offering the qualification in English.

Table 3: Engineering graduations in Mozambique in 2014

INSTITUTION	Agricultural	Chemical	Civil	Electrical & Electronics	Environmental	ICT	Mechanical	Mining & Metallurgy	Oil & gas	Railway
Public institutions										
Academia Militar (AM)							5			
Escola Superior de Ciências Náuticas (ESCN)						10	15			
Instituto Superior Politécnico de Gaza (ISPG)	31						11			
Instituto Superior Politécnico de Manica (ISPM)	56									
Instituto Superior Politécnico de Songo (ISPS)				NQ			NQ			
Instituto Superior Politécnico de Tete (ISPT)								28		
Universidade Eduardo Mondlane (UEM)	46	21	55	66	9	18	21		NQ	
Universidade Lurio (UniLurio)	24					9				
Universidade Pedagógica (UP)			NQ			NQ				
Universidade Zambeze (UniZambeze)	46		9		7	15	21			
Private institutions										
Instituto Superior de Ciência e Tecnologia Alberto Chipande	41									
Instituto Superior De Ciência E Tecnologia De Moçambique						25				
Instituto Superior de Transportes e Comunicações (ISUTC)			20			9	6			13
Universidade Católica De Moçambique (UCM)						48				
Universidade Jean Piaget De Moçambique (UJPM)			9			8				
Universidade Politecnica (A POLITECNICA)			34							
Universidade São Tomas De Moçambique (USTM)						22				
Universidade Técnica De Moçambique (UDM)			NQ	NQ		NQ	NQ			
Universidade Wutive (UniTiva)			NQ					NQ		
TOTAL										
Engineers (767)	244	21	136	66	16	164	79	28		13

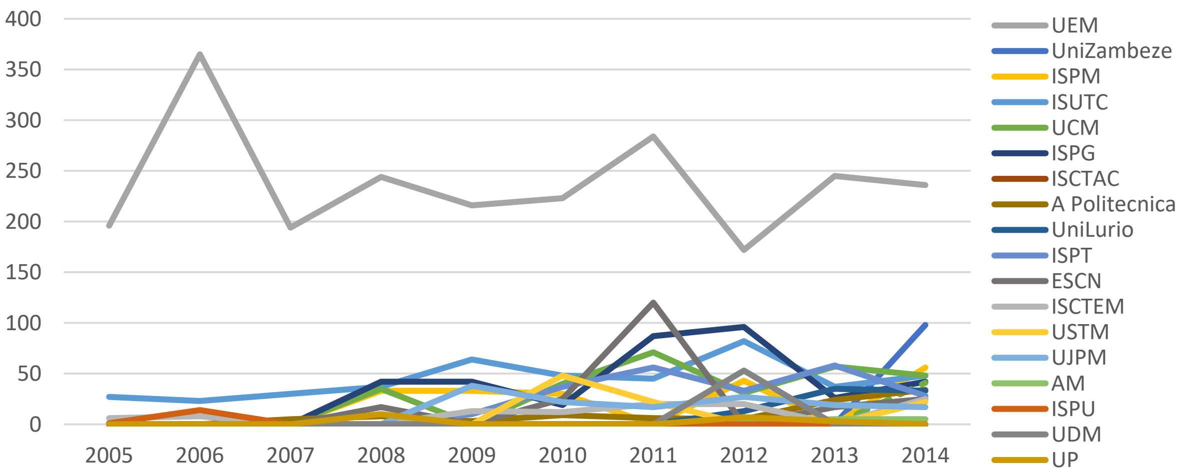
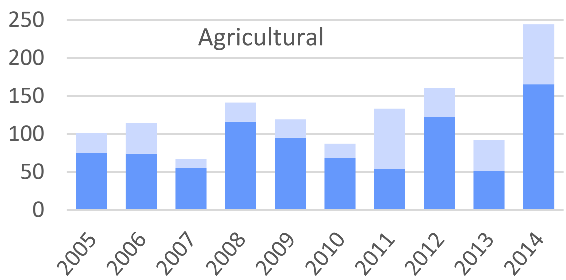
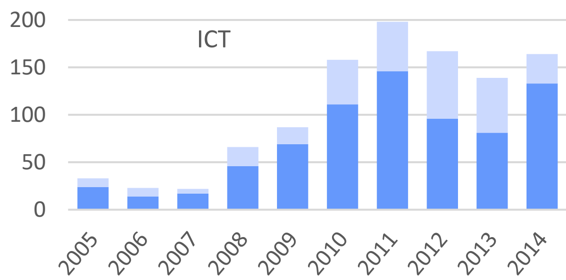


Figure 10: Engineering graduates by institution





MOZAMBIQUE

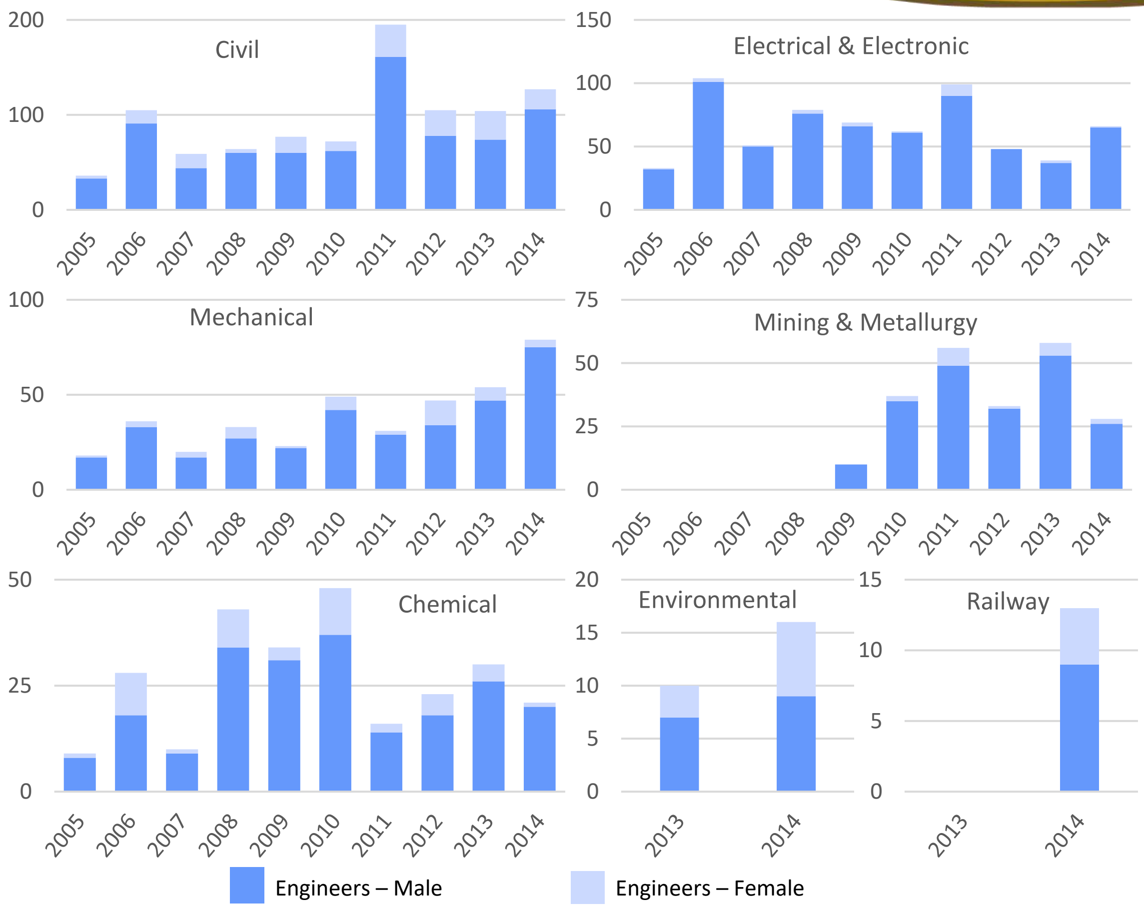


Figure 11: Engineering graduates by discipline and gender

Accreditation

Early engineering qualifications in Mozambique were based on the structure of those offered in Portugal. The Ordem dos Engenheiros de Moçambique (OrdEM) thus recognised the original engineering qualifications offered by the UEM as appropriate for the training of engineers. It has since recognised qualifications from a further three private institutions, namely Universidade Politecnica, the Instituto Superior De Ciência E Tecnologia De Moçambique and the ISUTC.

With the proliferation of universities in recent times, it has become necessary to set national standards. Decree-Law No 64/2007 was enacted to set up the National Council for the Evaluation of the Quality of Higher Education (CNAQ). Working with the SADC Technical Committee for Certification and Accreditation (TCCA) to ensure equivalence of qualifications in the region, and the mobility of graduates, CNAQ has developed a National Qualifications Framework (NQF) with 10 levels and has set the professional engineering degree at level 8. Work is underway to develop accreditation procedures for engineering qualifications, in partnership with the OrdEM. The range and complexity of subjects, lecturing capacity, facilities, laboratories, student selection and industry input are some of the many variables that will be considered.

Of concern is the fact that institutions need to offer engineering qualifications before they can be accredited, which means that the qualifications earned by those who complete their studies before institutions have been accredited will not be recognised by the OrdEM. At present there are many institutions offering qualifications that are neither recognised by the OrdEM nor accredited by CNAQ. The CNAQ has, however, accredited qualifications in four additional institutions with a lower rating than that acceptable to the OrdEM. Efforts at aligning the requirements of the two organisations are underway. Consideration is being given to using the Washington Accord guidelines.

Student mobility

In 2015, 561 Mozambicans were studying at South African universities, of whom 186 were studying by correspondence through the University of South Africa. A total of 11 engineering students graduated – four completing degrees, four completing BTechs and three completing national diplomas.

In terms of undergraduate studies, the Institute of Scholarships for Students (IBE), created by Decree No. 30/2007 and revised by Decree No. 24/2017, has a mission of ensuring the allocation, coordination and management of scholarships for academic and professional training abroad. Priority areas include engineering, the sciences and tourism. In 2017, there were some 1 500 students studying abroad, 70% of whom were in science and technology and 285 graduated. It is estimated that engineering accounted for 50% of those in science and technology, 77% of whom graduated from their first higher education qualification, suggesting that about 77 engineers graduated abroad.

Countries hosting the largest number of Mozambican students were (from largest to smallest) Algeria, China, Portugal, India, Russia, Malaysia, Japan and Tanzania, which together hosted 80%. A further 19 countries hosted the balance of students studying abroad.

The government also offers bursaries for engineering students to complete master's qualifications, to enhance the research capacity of the country. Where specialisation is not available within the country, it is suggested that students should select institutions in Brazil, India, China, Japan and elsewhere in Africa.

GRADUATE TRAINING

Once the tertiary education phase is complete, it is necessary for graduates to get structured training in the workplace, under professional supervision and mentorship, to develop to the level of competence required for professional registration, and to be able to take on work independently. There are a limited number of companies that offer formal graduate training – few public sector structures take on graduates, and only some of the large private companies offer such support. Many graduates are unable to find work opportunities after graduating, which limits the long-term development of engineering capacity in the country. Consideration needs to be given to developing and funding graduate training programmes.

PROFESSIONAL REGISTRATION

Ordemdos Engenheiros de Moçambique (OrdEM) – the Order of Engineers of Mozambique – was set up to register engineers in response to the Engineering Law 16/2002 which was first promulgated in June 2002. The Law states that the registration of engineers is mandatory for carrying out engineering activities in Mozambique. The Order is responsible for the entire career development of engineers, including:

- Accrediting higher education institutions to ensure that the standard of engineering qualifications is upheld
- Contributing to the structuring of engineers' careers
- Promoting, organising and supporting the ongoing training of its members and other engineering practitioners
- Providing technical and scientific collaboration requested by any entity in either the public or private sector, when there is public interest
- Ensuring the quality and safety of studies, projects and engineering works
- Taking disciplinary action against those acting unprofessionally
- Supporting the government by providing advice on public infrastructure development projects, and addressing other engineering matters if they are in the public interest.

By November 2018, the Order had 3 093 registered members, made up as shown in Table 4. This represented some 30% of all engineers in Mozambique. The Order has a range of member categories including registered, interns, honorary and corresponding members.

The OrdEM only registers qualified engineers, i.e. those who hold a degree or the legal equivalent. It is expected that engineers should apply technical sciences in research, design, manufacture, construction, repair, operation, maintenance, production, supervision and quality control of engineering projects, including the coordination and management of these and related activities.

Table 4: Registration with the OrdEM, 2018

DISCIPLINE	SENIOR	JUNIOR	TOTAL
Agronomy, including Forestry Engineering	207	71	278
Civil, including Mining Engineering	855	580	1435
Electrotechnical, including Informatics and Communications Engineering	405	270	675
Mechanical, including Transport, Maritime and Aeronautical Engineering	289	206	495
Chemical, including Environmental Engineering	112	98	210
TOTAL	**1 868**	**1 225**	**3 093**

MOZAMBIQUE

To date, recent graduates with accredited qualifications are registered as junior members of the OrdEM. Once they have had at least three years of experience in the engineering workplace, they may apply for senior registration status. Their upgrade is determined based on the submission of a detailed CV outlining their experience to date. The OrdEM is planning to adopt a competence-based approach to registration in the future and will assess the achievement of 10 outcomes.

VOLUNTARY ASSOCIATIONS AND CONTINUING PROFESSIONAL DEVELOPMENT (CPD)

As outlined above, the Order also offers CPD training for the continuing professional development of its members. Workshops, seminars and conferences are hosted throughout the year, based on interest or on the emergence of new technologies or trends. Conferences in partnership with Portuguese institutions are also hosted every two to three years to ensure that local engineers keep abreast of international best practice.

The Mozambican Association of Renewable Energies – AMER (Associação Moçambicana de Energias Renováveis) – is another voluntary association serving the interests of professionals operating in the renewable energy space.

WOMEN IN ENGINEERING

In 2011, UNESCO reported that the country's female gross enrolment ratio in tertiary education was just 3.73%. Odete Muximpua was the only woman engineer to graduate from her engineering class at Eduardo Mondlane University in 2005, and in 2015 she became the country's first woman engineer with a master's degree from a Mozambican university. Despite the low participation rate in higher education, engineering appears to have been well promoted among female learners as females make up almost 11% of the OrdEM's registrations.

THE WORKFORCE

It is estimated that there are around 11 000 engineers in the workforce. The age and gender distribution of OrdEM members is shown Figure 12. A gap in the 40s and early 50s can be seen, which indicates the disruption of studies during the civil war years. Students enrolling after the war would now be around 43 years of age. It can be seen that graduate numbers have built up again in the group below 43 years old.

THE PRIVATE SECTOR

The main employers in the private sector are consulting, contracting, manufacturing supplier and mining companies. Lower numbers are employed in small entrepreneurial companies, training organisations and other companies where engineering input is required, as well as many NGOs assisting with social infrastructure, rural development and enhancing farming methods.

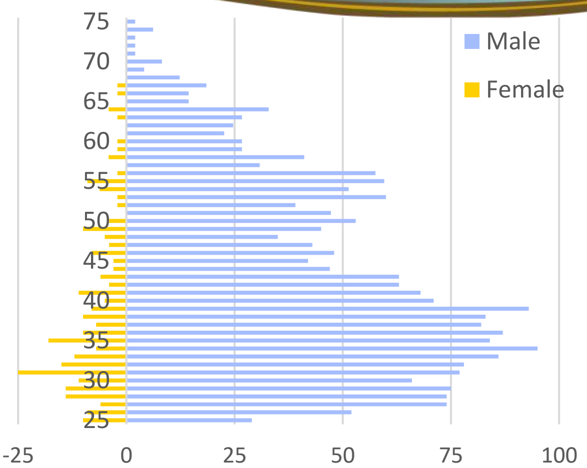


Figure 12: Membership of the OrdEM by age and gender

Consulting

There are some 63 consulting companies in Mozambique. Consultants are obliged to register with the Ministry of Public Works. Many belong to the Associação de Empresas Moçambicanas de Consultoria (AEMC) or the Association of Mozambican Consulting Companies, which was formed in 2002 to represent companies offering consultancy services operating in Mozambique. Unlike consulting associations in other SADC countries, the AEMC has corporate members from the range of built environment, scientific, financial, legal, health, social, environmental and other professions. The principal member must hold a degree and have at least eight years of experience in his or her field.

The AEMC aims to be an active voice in Mozambique, having as its vision the desire to contribute to promoting the quality of consulting services, assisting members to raise their level of competitiveness, professionalism, ethics and business standards through continuous training, collaboration and collegiality, and contributing to the country's development.

Contracting

Mozambique has an estimated 5 000 construction companies in total, employing some 166 000 people in 2014. Contracting is regulated under Art. 2. Decree N.º 83 of 2002. Conditions are revised from time to time. Contractors operating in Mozambique must obtain a licence with the National Directorate of Public Works.

These companies are graded according to their assets and their working and human capital to determine their ability to undertake projects of varying complexity and scope. There are seven grades and the depth of the companies' expertise and capital increases incrementally from one to seven.

Most local Mozambican firms fall between the first and fourth grade, with the third grade having the largest number. Distinguishing between foreign and local Mozambican firms is very difficult as the foreign firms register in Mozambique and adopt Portuguese names.

However, an interview with an official from the Department of Public Works confirmed that most foreign firms are located in the seventh grade, while the local Mozambican presence in that grade is small by comparison. This is echoed in other construction research findings. There is a quota on the number of foreign staff that companies may employ. For small companies no more than 10% of the staff may be foreign, and for large companies this drops to 5%. Companies need to motivate for permission to employ higher percentages in cases where specialist skills are not available locally, but they are expected to develop local skills as a condition of the quota relaxation.

The skills required by contractors per category are shown in Table 5. Unfortunately, 2005 is the most recent date for which details per category could be found. In Decree N.º 77/2015, the maximum values per class were increased to four times the values shown in Table 5, but the capital requirements and technical team requirements were unchanged.

The Mozambican Federation of Contractors (FME) is a voluntary association representing the interests of contractors. The FME wishes to create a national database of contractors to monitor the industry and be able to advise government better on what to look for in terms of licensing criteria. A recently launched voluntary association, the Association of Building Contractors and Public Works of Sofala (AECOPS) seeks to represent the interests of contactors in their province.

Manufacturing

According to the World Bank, most Mozambican manufacturing firms are very small (having fewer than 10 employees), with 90% of them being micro or small companies. They produce relatively homogeneous products using basic technology and sell mostly to private individuals in the same locality, with limited linkages to the rest of the economy. It is estimated that there are some 520 MSMEs. Large firms are mostly dominated by foreign companies and are capital intensive, such as the Mozal Aluminium Smelter. The 2014 labour force survey indicated that some 60 367 people were employed in the sector.

Various private sector associations represent the interests of manufacturers and the business community, including the Associação Industrial de Mozambique (AIMO); the Chamber of Commerce Mozambique and the Confederation of Business Associations (CTA) Confederação das Associações Económicas de Moçambique.

Mining

The mining sector employed 41 800 in 2014. Currently, most of Mozambique's mining and mineral processing operations are privately owned, including cement plants, aluminium smelters and gas processing plants.

THE PUBLIC SECTOR

Many engineering practitioners are required in the public sector, including in municipalities, to plan new services, issue project tenders and oversee the delivery of, and operate and maintain infrastructure. Table 6 shows those Ministries and structures that are the main employers of engineering skills.

Table 5: Classification of construction companies and minimum capital requirement (2005)

CLASS	NUMBER OF FIRMS	MAXIMUM VALUE PER CLASS (000' meitcas)	MINIMUM CAPITAL REQUIREMENT (000' meitcas)	PERMANENT TECHNICAL TEAM
1	156	350	20	1 civil builder
2	248	850	50	1 Civil builder with five years' experience
3	1 283	2 500	150	1 mid-level engineer and 1 civil builder
4	314	5 000	500	1 engineer or architect and 1 mid-level engineer
5	226	15 000	1 500	2 engineers or 1 engineer and 1 architect or 1 engineer to 2 mid-level engineers
6	49	50 000	5 000	3 engineers and 1 mid-level engineer or 2 engineers, 1 architect and 1 mid-level engineer
7	214	Over 50 000	10 000	5 engineers and 2 mid-level engineers or 3 engineers, 1 architect and 2 mid-level engineers with more than 5 years' experience

MOZAMBIQUE

Table 6: Ministries employing engineering practitioners

MINISTRY/STRUCTURE
Ministry of State Administration and Public Function – *MAEFP (Ministério da Administração Estatal e Função Pública)* • Direcção Nacional de Administração (Local DNAL) • Direcção Nacional de Desenvolvimento Autárquico (Municipal DNDA))
Ministry of Labour, Employment and Social Security – MITESS (*Ministério do Trabalho, Emprego e Segurança Social)*
Ministry of National Defence – Ministério da Defesa Nacional
Ministry of Transport and Communications – MTC (Ministério dos Transportes e Comunicação) • National Communications Institute of Mozambique – INCM (Instituto Nacional das Comunicações de Moçambique) • Mozambique Telecommunications – TDM (Telecomunicações de Moçambique) • Mozambique Cellular – MCEL (Moçambique Celular) • National Institute of Meteorology – INAM (Instituto Nacional de Metereologia) • Ports and Railways Company of Mozambique – CFM (Caminhos de Ferro de Moçambique) • Mozambican Civil Aviation Institute – IACM (Instituto de Aviação Civil de Moçambique) • Mozambican AirportsCompany – Aeroportos de Moçambique • Mozambican Company of Dredgers – EMODRAGA EP (Empresa Moçambicana de Dragagens)
Ministry of Education and Human Development – Ministério da Educação e Desenvolvimento Humano
Ministry of Agriculture and Food Safety – MASA (Ministério da Agricultura e Segurança Alimentar) • Mozambique InstituteofAgricultural Research – IIAM (Instituto de Investigação Agrária de Moçambique)
Minisrtry of Land, Environmental and Rural Development – Ministério da Terra, Ambiente e Desenvolvimento Rural
Ministry of the Sea, Inland Waters and Fisheries – Ministério do Mar, Águas Interiores e Pescas
Ministry of Mineral Resources and Energy – MIREME (Ministério dos Recursos Minerais e Energia) • National Institute of Petroleum – INP (Instituto Nacional de Petróleo) • National Enterprise of Hydrocarbons – ENH (Empresa Nacional de Hidrocarbonetos) • Mozambican Hydrocarbons Company – CMH (Companhia Moçambicana de Hidrocarbonetos) • Energy Fund – FUNAE (Fundo de Energia) • National Electricity Regulator Board – ARENE (Autoridade Reguladora de Energia) • Hydroelectric Cahora Bassa – HCB (Hidroeléctrica de Cahora Bassa) • Electricity from Mozambique – EDM (Electricidade de Moçambique) • PETROMOC (Petróleos de Moçambique) • Instituto Nacional de Minas (INAMI) • Direcção Nacional de Geologia e Minas (DNGM)
Ministry of Public Works, Housing and Water Resources – MOPHRH (Ministério das Obras Públicas, Habitação e Recursos Hídricos) • National Directorate of Public Works – Direcção Nacional de Edifícios • National Directorate of Urbanisation and Housing – Direcção Nacional de Urbanização e Habitação • National Directorate of Water – Direcção Nacional de Águas • Water Research Institute – IIA (Instituto de Investigação em Água) • Water Supply Regulatory Board – CRA (Conselho de Regulação de Águas) • National Roads Administration – ANE (Administração Nacional de Estradas)
Ministry of Industry and Trade – MIC (Ministério da Indústria e Comércio) • National Directorate of Industry • National Directorate of Internal Trade • National Directorate for Foreign Trade
Ministry of Science and Technology, Higher and Technical Education – MCTESTP (Ministério da Ciência e Tecnologia, Ensino Superior e Técnico Profissional) • National Council for Quality Assessment of Higher Education – CNAQ (O Conselho Nacional de Avaliação da Qualidade do Ensino Superior)

There are substantial plans to develop or upgrade roads, rail and ports, and to increase access to safe drinking water, improved sanitation and energy, which will require engineering skills. Limited training is, however, taking place to develop a pipeline of engineering skills coming into the public sector. Furthermore, many departments report vacancies, and difficulty with attracting experienced staff due to poor salaries. Owing to financial constraints, new staff are not being appointed as experienced staff retire, and capacity is reducing as the development workload is increasing.

MIGRATION TRENDS

Analysis of the United Nations Population Division statistics for 2015 shows a small net gain of professionals to Mozambique, coming mostly from neighbouring states. Eighty-six per cent of professional emigrants moved to South Africa.

ENGINEERING NUMBERS AND NEEDS

Considering all the engineering activities and developments in recent years, engineers have clearly played a key role in the development of the Mozambican economy. However, considering all the developments planned, it is evident that more qualified and well-experienced engineers will be needed.

In the absence of detailed numbers of those working in each sector, due to limited returns from public and private sector organisations alike, projections are based on there being some 11 000 engineers in the workforce, as estimated by the OrdEM. Currently, around 770 engineers graduate in Mozambique per year, a further 70 or 80 are available to return from overseas studies and a further 160 will start coming on stream from 2020.

Figure 13 shows the current engineers in the workforce, the losses that will occur over the 18-year period to 2035 due to retirement, mobility and mortality, and the growth in engineering capacity if engineering graduations increase at 2% per year over the period. The blue dotted line shows the growth in skills that would be required at the 2017 GDP growth rate of 3.7% and the green dotted line shows the growth based on the 2018–2023 GDP projection of 5.1%. A 70% employment elasticity factor has been used to extrapolate the employment demand.*[1]

At the projected growth rate of 5.1% there will be an excess of graduates. The number graduating can only be absorbed if government reprioritises its budgets and invests in infrastructure development and maintenance, and if the private sector is able to attract investment and expand to achieve the industrialisation targets. This growth is anticipated with the development of the gas industry for which the mix of disciplines graduating needs to be considered. The number of chemical engineers graduating appears to be low and students should be encouraged to register for the new oil and gas qualifications.

The number of graduates relative to experienced staff in the workplace will, however, be high, and rigorous structured programmes will be required to ensure that graduates are adequately trained to become independent professionals.

The proliferation of higher education institutions offering engineering qualifications is a concern. Consolidation is called for and institutions with the capacity and resources to offer quality education should be supported to achieve the standards as required by CNAQ. Approval to offer engineering programmes for those with limited resources should be withdrawn. Attention should be paid to those institutions in which the proportion of students to full-time lecturer support is particualrly high, as in this case students are getting limited, if any, support outside of lecturing time.

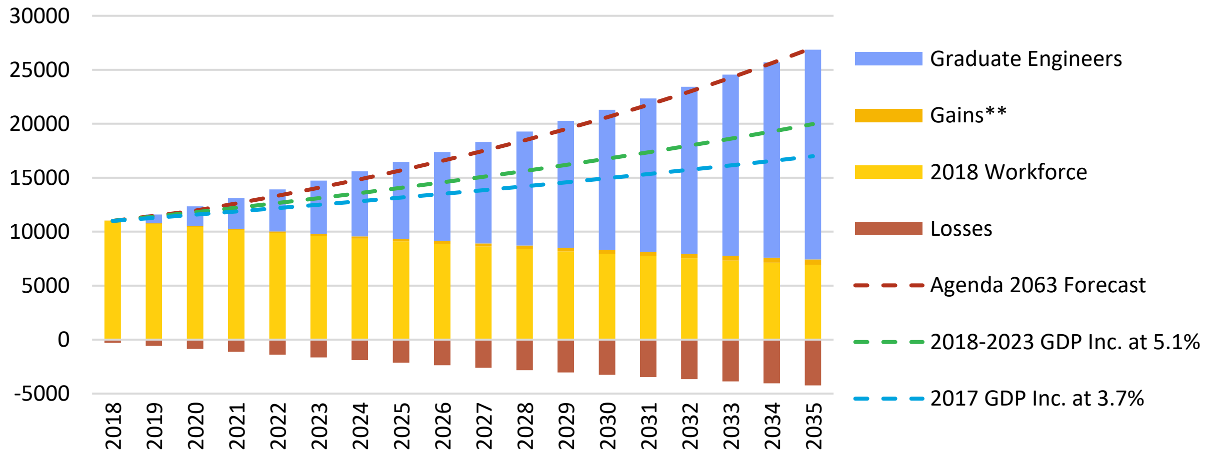


Figure 13: Flow of engineers based on a 2% increase in graduate rate per year

***Excludes international engineering practitioners in the country on short-term contracts*

KEY RECOMMENDATIONS

To develop a sound pool of engineering professionals, able to contribute to the well-being of Mozambique, the following should be considered:

Schooling

- **Primary and secondary education:** Address the weaknesses in primary and secondary education, and increase the number completing secondary education with acceptable results.
- **Career guidance**: Expand career guidance to attract high-calibre entrants into the engineering profession, incorporating programmes to reach female learners, and rural and low-income areas.

*[1] Employment elasticity is a measure of the percentage change in employment associated with a 1% change in economic growth. If the growth is likely to be in agriculture, the percentage could be lower, as growth in that sector generally has to do with productivity gains and not employment, while if the growth is likely to be in high-tech manufacturing, the elasticity factor maybe more than 100%.

- **Bursaries**: Provide bursaries to attract those who excel in mathematics and science to study engineering.

Higher education

- **Consolidation:** Consolidate engineering studies into well-resourced institutions to ensure quality output.
- **Accreditation:** CNAQ to develop a rigorous national accreditation programme in collaboration with the OrdEM to ensure the quality of engineering education using the guidelines of the Washington Accord
  - Encourage institutions to develop adequate complex engineering problem-solving content and graduate attributes to satisfy the requirements of the Accord.
  - Create awareness of accredited qualifications and warn learners of those that will not lead to registration as engineering professionals.
  - Withdraw qualifications which do not meet accreditation requirements.
- **Industry liaison:** Liaise with industry on a regular basis to ensure that curricula, methods, software and equipment are relevant and up to date.
- **Curricula:** Provide funding to research, modernise or develop curricula and material where required.
- **Facilities:** Raise funding to upgrade lecture theatres, libraries and laboratory facilities where required.
- **Resources:** Raise funding for computers, engineering software, access to online reference material, and laboratory and other equipment, and ensure adequate support to offer technology-relevant training.
- **Attract and retain academics:** Improve conditions of service, support and packages to attract, retain and appoint additional academics.
- **Teaching methods:** Apply the latest methods and technology for teaching, and train academics in 21st century approaches to teaching.
- **Academic development:** Provide funding for lecturer post-graduate development and facilitate opportunities for academics to gain experience in industry.
- **Rail engineering:** Support the development of the rail qualification and offer it to the region in English.
- **Oil and gas and chemical engineering:** Encourage increased enrolments in chemical engineering and in the new oil and gas qualifications.

Graduate training

- **Develop programmes:** Develop national graduate training programmes to ensure graduates achieve the level of competence required by industry and for professional registration.
- **Private sector incentives:** Offer incentives for private sector companies to develop graduates.
- **Public sector support:** Ensure that public sector structures take on and train graduates and that they are absorbed and developed through the ranks.
- **Institutional support:** Institutionalise graduate training in all organisations by setting KPIs for experienced staff to act as supervisors and mentors.
- **Project support:** Make graduate training a requirement of all public sector projects and ensure that the progress of graduates is monitored, and penalties are imposed for non-compliance.

Registration of engineering professionals

- **Registration:** Encourage the registration of all engineers with the OrdEM.

Continuing development

- **CPD:** Support the participation of engineering practitioners in CPD activities.
- **Post-graduate studies:** Provide post-graduate bursaries to develop specialists.
- **Develop managers and leaders:** Encourage industry to continue investing in graduates after professional registration to grow management and leadership capabilities.

Service providers

- **Regulations:** Expand the regulations covering the Public Works and Civil Construction Contractors to:
  - Ensure that there are requirements for consultants and contractors to train graduates, artisans and other construction-related skills.
  - Ensure that international consultants provide all calculations, drawings, operating manuals and other reference material in Portuguese.
  - Ensure that local consultants, along with the client, check that design proposals address local needs and customs and that design calculations comply with national codes and standards.
- **Quality:** Implement quality assurance on all projects and enforce penalties for poor performance.

Public sector

- **Economic infrastructure:** Invest in the development of economic infrastructure such as electricity, roads, rail, ports and airports, and address the supply of water services.
- **Maintenance:** Invest in maintenance to preserve infrastructure.

- **Tariffs and payment:** Review and increase tariffs where appropriate, enhance domestic revenue collection and demand management to fund development.
- **Technical capacity:** Reprioritise budgets to fill vacant posts and build technical capacity, ensure that salaries are competitive and develop succession plans to make the public sector an employer of choice.
- **Technical decision-makers:** Ensure that engineers are employed in senior decision-making posts.

Industry-wide collaboration

OrdEm and other professional bodies to work together to share knowledge, exchange best practice and be recognised by government, to advise on and endorse infrastructure development proposals, tertiary qualifications and graduate training programmes.

ACKNOWLEGEMENTS

Progress would not have been made in Mozambique without the assistance of Mike Muller and Nelson Beete to make initial contacts and of Ilidio Maheche of the Ministry of Science and Technology, Higher and Technical Education (MCTESTP) to make a focal point person available to assist with the project. From there, thanks to the President and Registrar of the OrdEM, Ibraimo Remane, and to Eunice Abreu who, together with Sergio Pereira, set up meetings, collected data and offered input. Thank you, too, to Prof. Charifo Ali, Dean of Engineering at the Eduardo Mondlane University, and his team of academics for data and insights and to the many passionate engineers in various engineering ministries, contracting and consulting firms who made contributions.

SOURCES OF INFORMATION

Data and information were gathered during meetings and interviews, and via email. SADC reports, master plans and strategies as listed under *Plans and Strategies*, and many standard international sets of data as listed in Chapter 5, *Research Approach,* were also consulted. Further information was gathered from news articles, portals such as The Club of Mozambique and Macauhub (which publishes news covering the relationship between China and Lusophone countries), etc., and from Labour Force Surveys. Comprehensive documents focusing on specific issues in Mozambique as listed below were other sources of information.

Bailey, T., Cloete, N. and Pillay, P. 2010. *Universities and economic development in Africa. Case study: Mozambique and Eduardo Mondlane University*. Pretoria: Higher Education Research and Advocacy Network in Africa (HERANA), University of Cambridge-Africa, and Centre for Higher Education Transformation (CHET).

Catine, O. 2015. *Overview of the cotton industry in Mozambique*. Washington, DC: International Cotton Advisory Committee (ICAC)

Eaglestone Inc. 2014. *The telecoms sector in Mozambique*. Maputo.

FAO (Food and Agriculture Organization of the United Nations). 2013. *Analysis of incentives and disincentives for tobacco in Mozambique.* Washington, DC.

Glover, S., Salvucci, V. and Jones, S. 2016. *Where is commercial farming expanding in Mozambique*? Working Paper Series 159, World Institute for Development Economic Research, United Nations University.

Ledger, T. 2017. *Case study on the forestry regional value chain in southern Africa: South Africa, Mozambique and Tanzania*. TIPS Report for the Department of Trade and Industry. Pretoria: Trade & Industrial Policy Strategies (TIPS).

Martins, Z., Anjo, B.T. and Amaro, S. 2017. *Mozambique skills baseline study*. Maputo: Unidade de Processamento de Ideias (UPI).

MCTEST (Ministério da Ciência e Tecnologia, Ensino Superior e Técnico Profissional). *Dados Estatísticos sobre o Ensino Superior [graduate data] em Moçambique 2014 and 201*5. Maputo.

Salinger, L. and Ennis, C. 2014. *Manufacturing in Mozambique*. USAID.

Sutton, J. 2014. *An Enterprise Map of Mozambique*. London: International Growth Centre.

University of Copenhagen, Ministério da Economia e Finanças and United Nations University 2017. *Survey of Mozambican Manufacturing Firm*s. Copenhagen, Maputo and Helsinki.

USAID (United States Agency for International Development) Trade Hub Southern Africa. *Mozambique textile and apparel brief*. Available at: www.satradehub.org

World Bank. 2016. *Mozambique: Jobs for development. Let's Work Program*. Washington, DC: World Bank.

NAMIBIA

NAMIBIA is the most sparsely populated country in the SADC region and one of the least densely populated countries in the world. It shares borders with Angola and Zambia in the north, Botswana in the east and South Africa in the south, and is bounded by the Atlantic Ocean in the west.

The country is home to two deserts, the Namib (said to be the oldest desert in the world) and the Kalahari, and is the driest country in SADC, receiving an average of 285 mm rainfall per year.

Namibia is one of Africa's largest exporters of non-fuel minerals and in 2016 was the world's sixth-largest producer of uranium. Rich alluvial diamond deposits make Namibia a primary source for gem-quality diamonds. Marine mining has become increasingly important as the terrestrial diamond supply has dwindled.

Although Namibia is an upper-middle-income developing country, 28% of the labour force was unemployed in 2016, with more recent reports suggesting that this could be as high as 37%. In 2017, Namibia was rated as having the sixth-highest prevalence of HIV/AIDS in the world estimated at 8.4%.

Windhoek is the capital and the most populous and important city as it is a major industrial centre. Considerable urbanisation has taken place, largely due to rural poverty attracting people to the city to improve their livelihoods and the re-gazetting of some urban areas. The rapid growth is visible in the informal settlements where residents occupy land illegally.

In 2004, Namibia adopted Vision 2030, spelling out the country's development programmes and strategies to achieve its national objectives. The National Planning Commission (NPC) has developed five-year National Development Plans (NDPs) since independence, with NDP 4 covering the five-year period from 2012/2013 to 2016/2017 and a further three plans, NDP 5, NDP 6 and NDP 7, being envisaged to cover the period until 2030.

THE ECONOMY

The Namibian economy depends on the mining sector, which employs only 1.3% of the workforce and few unskilled labourers. As a result, most workers must rely on subsistence farming for their livelihood. The country has seen impressive growth rates, often topping 10% since 2004, mainly due to mining. However, mining exports have reduced due to a drop in commodity prices. Other earners are agriculture and fish processing. Recent droughts and army worm infestations have had an impact on agricultural production and overfishing has reduced fish processing. All these negative factors, coupled with a growing public sector workforce, accepting expensive international funding, and corruption, saw the growth in GDP plummet to just above zero in 2015.

PLANS AND STRATEGIES

To address development, several important plans and policies have been drawn up, which include:

- **Vision 2030** the aim of which is to ensure that Namibia becomes an industrialised country of equal opportunities, which is globally competitive.
- **Fifth National Development Plan (NDP5) (2017–2022)** which is the nation's blueprint for national development and charts a course towards achieving the targets outlined in Vision 2030, the most important of which is rapid industrialisation.
- **Harambee Prosperity Plan (HPP)** which has been developed to complement the NDP and Vision 2030. Expected outcomes include a high-

Table 1: Namibian metrics

Population	
Total	2 369 000
Urban	45.8%
Rural	54.2%
Poverty, HIV, Unemployment	
Below international poverty line	22.6%
HIV-positive	8.4%
Unemployment	28.1%
Human Development Index	0.628
Electricity	
Production kWh	1.4bn
Consumed kWh	3.89bn
Airports and Ports	
Airports	112
- Paved	19
- Unpaved	93
Kilometres of Services	
Roads	44 138
- Paved	6 387
- Unpaved	37 751
Rail	2 628
Africa Infrastructure Development Index	28.65
Access to Services	
Access to safe drinking water	92%
- Urban	98%
- Rural	87%
Access to improved sanitation	32%
- Urban	56%
- Rural	17%
Access to electricity	32%
- Urban	50%
- Rural	17%
Telephones	187 853
Mobile phones	2 659 951
Internet users	31%

performance and citizen-centred culture of service delivery, a reputable and competitive vocational education training system, and a spirit of entrepreneurship and enterprise development.

- **Sustainable Urban Transport Master Plan for Windhoek 2032** (known as Move Windhoek) which covers Windhoek, including Rehoboth, Okahandja and the Hosea Kutako International Airport. The Master Plan is a long-term approach to develop an affordable, accessible, attractive and efficient public and non-motorised transport system.
- **Green Scheme Programme** which encourages the development of irrigation-based agronomic production to increase the contribution of agriculture to the GDP, achieve the social development and upliftment of communities, and promote human resources and skills development within the irrigation subsector.
- **Namibia's Industrial Policy 2030** which is anchored in Vision 2030 and envisages that by 2030 Namibia should be characterised as *'… a prosperous and industrialised country, developed by her human resources, enjoying peace, harmony and political stability'.*
- **Growth at Home Strategy** which provides a road map for the implementation of the Industrial Policy and focuses on supporting value addition, securing market access and improving the investment climate and conditions.
- **National Human Resources Plan (2010–2025)** which aims to achieve increased economic growth and employment creation, and the skills and knowledge required for a knowledge-based economy.

ENGINEERING ACTIVITIES

All five of the game changers listed in NDP 5 have one sector in common – engineering. The game changers are: increase investment in infrastructure development; increase productivity in agriculture, especially for smallholder farmers; invest in quality technical skills development; improve value addition in natural resources; achieve industrial development through local procurement.

Figure 1 shows the contribution of engineering-related economic activities to the country's GDP. The largest sector mining followed by manufacturing. Considering each in turn will give a picture of the activities, trends, challenges and opportunities for the engineering profession to contribute to Namibia's growth.

AGRICULTURE

The agricultural sector supports over 70% of the country's population and covers nearly 80% of the surface area. It also supports other sectors, such as transport and manufacturing. The negative impacts of natural disasters, such as floods, periodic droughts and diseases, result in Namibia being rated as the world's seventh most-at-risk country in terms of related agricultural losses, which affect not only the economy and the environment, but also and most importantly, the people. The lack of modernisation in farming techniques and infrastructure further reduces the sector's contribution.

Given the dry conditions, irrigation is essential to increase food production. In 2011 some 8 600 ha were reported to be under irrigation and the government has developed plans to add a further 27 000 by 2030.

An early initiative, the Green Scheme Programme, was initiated in 2003 to irrigate more land and encourage local sourcing of agricultural products. Retailers of fruits, vegetables and other crop products are expected to purchase 27.5% of their fresh produce from local farmers. Challenges experienced by the Green Scheme Programme included limited success with fund raising and lack of

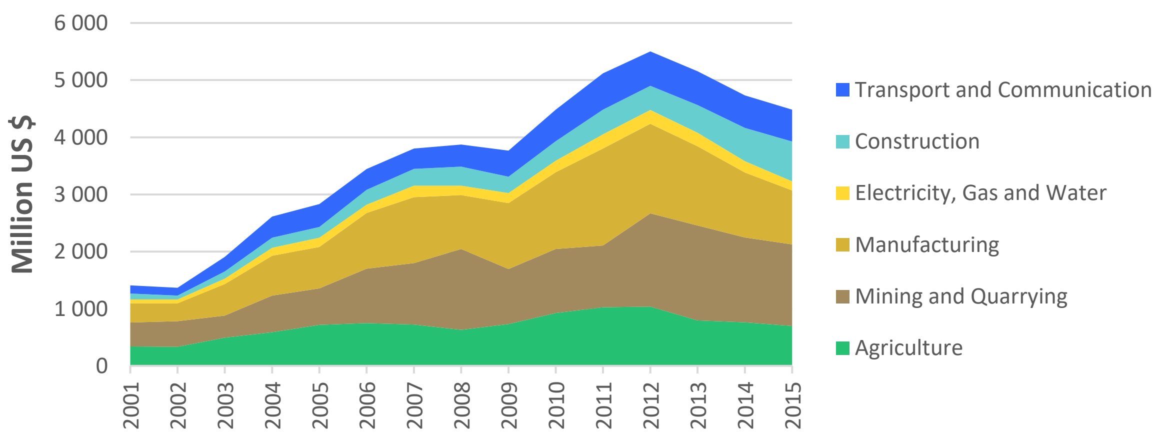


Figure 1: GPD per engineering-related economic activity (42% of the GDP)

technical expertise, such as agricultural engineers, as skills in farming approaches and mechanisation were required. The private sector has now taken up the challenge to increase the area under irrigation.

The agricultural sector can be divided into two distinct subsectors: the subsistence-based, high-labour, low-technology communal subsector, and the capital-intensive, relatively well-developed and export-oriented commercial subsector.

Subsistence farming

Most Namibians depend on subsistence farming for their food security. In the northern part of the country, where about 60% of the population lives, the main crop is *mahangu*, also known as pearl millet, which is a subsistence rain-fed cereal crop. Enough is produced to meet local demand. Small-scale livestock farming is also practised. The production of smallholders is low, which is attributed to limited access to inputs, poor soils and limited access to land; frequent occurrence of natural disasters, such as drought and floods; and lack of access to sustained technological progress.

Commercial farming

Commercial farming occupies some 40% of the land area and focuses primarily on livestock ranching. Cattle raising is predominant in the central and northern regions, while karakul sheep and goat farming are concentrated in the more arid southern regions. Through the export of beef and mutton, the livestock subsector is the single largest agricultural contributor to the GDP.

Although most of the several thousand maize and *mahangu* producers are small communal farmers, there are some 250 large-scale commercial farmers who produce about half the country's demand for white maize. About half of the output is irrigated. Since 2002, *mahangu* products have been made commercially available by Namib Mills. Local producers sell directly to the millers who sell directly to local retailers. There are a few wheat producers, all of whom are large-scale commercial farmers using irrigation to meet about 15% of local demand.

Fisheries

Namibia ranks as the third-largest African capture fisheries nation, with most of the fishing industry concentrated in Walvis Bay, the only deep-sea port. Lüderitz is, however, the primary processing centre for lobster, crab and oysters.

Namibia's fisheries industry is a raw material producer and most catches are exported as fresh, chilled or frozen products, with only limited value addition being done in Namibia.

Forestry

The forests of Namibia, also described as dry semi-open to open woodlands, occur mainly in the deep aeolian Kalahari sands, in the north-central and north-eastern parts of the country.

Deforestation in northern Namibia is taking place as a result of the sale of poles, firewood and other forest products, which are available throughout the year. Through the Community-Based Indigenous Forest Management Project communities are being assisted to sustain their indigenous forests.

MINING AND QUARRYING

Mining is the biggest contributor to Namibia's economy in terms of revenue, accounting for some 25% of the income and contributing 11.6% to the GDP in 2014. Most of the revenue comes from diamond mining. Namibia is not only a major producer of gem-quality diamonds, but also produces uranium oxide, special high-grade zinc, acid-grade fluorspar, gold bullion, blister copper, lead concentrate, salt and dimension stone. In 2016 there were 17 major mining companies operating in Namibia. Of concern is the fact that many of the older mines only have an expected remaining life to 2020 or 2025.

However, exploration and development are ongoing. In 2015 and 2016, the Husab Uranium Mine, the Otjikoto Gold Mine, the Lodestone Dordabis Iron Ore Mine and the Dundee Precious Metals Tsumeb (DPMT) Sulphuric Acid Plant came into production. The expansion of the fluorspar, graphite and gold mines continued. Offshore diamond development and extensive exploration for base metals, diamonds, gold, natural gas, uranium and seabed minerals will

Figure 2: Alluvial diamond mining
(Courtesy: Namdeb)

ensure that mining remains a key contributor to the economy for a long time to come.

Cause for concern is, however, the shortage of technical skills. The Mining and Quarrying Sector Skills Plan (SSP) of June 2014 indicated that the industry was short of some 400 chemical, civil, electrical, process, project, mechanical, metallurgical and mine engineers and technicians, and the shortage was expected to grow to some 580 by 2020. As a result, the University of Namibia (UNAM) plans to establish marine and mining engineering training institutions at the coast, which will also focus on the ocean economy and mineral beneficiation.

Over and above a shortage of engineering skills, the main challenges faced by the sector include insufficient rail services, power supply, water shortages, and the introduction of policies that could stunt investment.

MANUFACTURING

The most important manufacturing subsectors are food production and metals, as can be seen in Figure 3. Basic Metals largely relate to the processing of copper and zinc, while Other includes textile, clothing and wooden products. Unfortunately, up-to-date details per subsector were not readily available. However, despite many policies and tax incentives over the years, including Export Processing Zone Incentives to promote manufacturing, the sector's overall contribution to the economy has hardly changed.

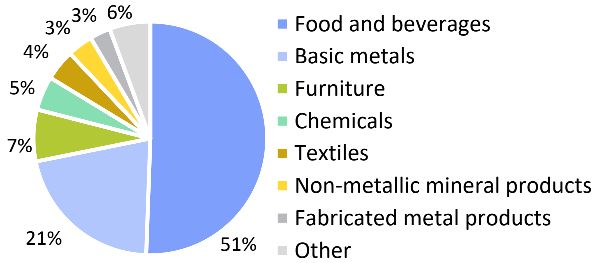


Figure 3: Manufacturing output per subsector
(Bank of Namibia 2004)

The Growth at Home strategy, announced in July 2013, promotes adding value to local raw materials before export to achieve targets set for 2030 by the Industrial Policy. The specific sectors targeted are mining and mineral beneficiation; agriculture and agro-processing; and fish and fish processing. The NDP4 has identified education, skills development and infrastructure development as key issues that will enable Namibia's industrialisation. Without energy, water, an efficient rail network and effective ports, progress will be impeded. Currently, the condition of rail is such that most products are moved by road, making transport costs high and increasing the cost of living.

The Industrial Policy and the Growth at Home strategy are hampered by lack of funding, although budget was initially set aside. The SME Bank set up to support industry has gone into liquidation.

Food and beverages

Processed meat (including game – chilled, frozen, dried and canned), processed fish (including filleted, canned and smoked), fish oil, fish meal, milk and dairy products are produced locally. Due to the extent of livestock farming, large volumes of animal feed are also manufactured.

Crop processing includes the milling of maize, *mahangu* and wheat; the production of peanut butter and tomato sauce; oil pressing from plant seeds; and juice extraction from fruit. Upstream industries include the production of bread, biscuits (cookies), cereal, pasta and confectionery, and the brewing of various alcohols, including beers, wines and spirits, although hops and other ingredients need to be imported. Carbonated drinks are also produced locally under licence, but in 2016, Coca-Cola, along with other agro-processing companies, needed to reduce production due to water shortages.

Textiles, clothing and leather

Although cotton is grown in Namibia, there is no ginnery, so all raw materials are exported and textiles for Cut, Make, Trim (CMT) garments and linen are imported. Given the extent of livestock farming, the manufacture of leather goods includes bags, belts, shoes, sandals, horse reins, etc., most of which are handmade.

Timber, pulp, paper and packaging

Bush encroachment covers about 45 million ha of the country's savannas, reducing livestock productivity, groundwater recharge and soil moisture content. Along with other timbers, encroacher bush is used as firewood and for the production of charcoal, wood chips, pellets, animal feed, poles, wood-cement bonded bricks or boards, medium-density fibre boards, wood-plastic composites; and, on a small scale, parquet, shingles, wooden frames and kitchen boards, sticks and handles for tools; smoking/aromatic material; and carving. The industry faces technical problems with chippers and extruders, which are not adapted to Namibian species.

A range of toilet and tissue papers, fine and craft paper, and corrugated packaging materials is manufactured using, in most cases, imported material. Plans are underway to establish a multi-million-dollar pulp and paper manufacturing plant in Gobabis.

Plastics, chemicals and other non-metallic mineral products

In terms of plastics, packaging material, tanks, plastic furniture and household goods are manufactured in Namibia, but all plastic pipes are imported.

The domestic chemical industry remains in its infancy, largely restricted to the manufacturing of cleaning and paint products. The main challenges faced in developing the industry are the lack of suitably skilled labour, water, cheap energy and economies of scale.

The government is exploring the salt value chain. A large share of the raw salt produced is exported to southern and western African countries, where it is used as an input into chlorine and caustic soda production, as a supplement to animal feed, and as a feedstock for refined table salt. Namibia's domestic use of salt is mainly confined to fish and other food processing, and household consumption.

The only cement production plant in Namibia was opened in 2011 and is one of the most technologically advanced in Africa. A second plant, just outside Otjiwarongo, has been constructed, which commenced operations in late 2018 and promised to double production in the country.

Pharmaceuticals

Namibia is home to medicinal plants such as Devil's Claw, Marula trees and !Nara plants. Products made from indigenous plants attract high value on the world market due to their organic medicinal properties. With the world demanding clean or organic alternative remedies, Namibia has the potential to play a vital role in this industry and it should prioritise this sector.

Metal industries, machinery and equipment

Namibia does not have its own steel production facilities, being fully dependent on imports. The range of metal products manufactured is limited to construction materials such as reinforcing bars, tubes, pipes, steel and aluminium doors and window frames, burglar bars, wire, fencing, formwork, sheeting, rainwater goods, etc. Trailers and aluminium boats are also manufactured on a small scale.

Many products could be made from the minerals mined, ranging from lead for storage batteries to zinc-based fireproofing chemicals. However, value addition often requires the introduction of new technology, including automation, and challenges such as the shortage of local capital and technical skills, scarce water supply, long distances between mineral deposits, markets and export destinations, and the size of operations required limit opportunities for mineral beneficiation.

Dundee Precious Metals' Tsumeb copper smelter is a beneficiation success story, as it is one of a few in the world that can treat complex copper concentrates containing arsenic. It has therefore been able to conclude long-term contracts with many countries to treat their concentrates. Blister copper, sulphuric acid and arsenic trioxide are smelter by-products.

Machinery and equipment are imported, except for some motor parts, which are manufactured in Walvis Bay, and a small range of pipes, valves and pumps. Vehicles are also imported, except for a range of military and agricultural vehicles, which have been designed and manufactured by Windhoeker Maschinenfabrik since 1939. The production of Peugeot and Opel vehicles is, however, set to commence in Walvis Bay towards the end of 2018.

ELECTRICITY, GAS AND WATER

Electricity

In 2013, only 32% of the population had access to electricity, made up of 50% of the urban population and 17% of the rural population.

According to the Rural Electricity Distribution Master Plan (REDMP) adopted in 2000, out of the 8 858 identified unelectrified rural settlements, only 1 543 have been scheduled for electrification within the 20 year plan, but 100% of the rural population should have access to energy by 2030.

Namibia's national power utility is NamPower, which has a generation capacity under ideal conditions of 513 MW from the local Ruacana, Anixas, Paratus and Van Eck Power Stations. They plan to increase the capacity to 930 MW in 2025 and to 1330 MW in 2035.

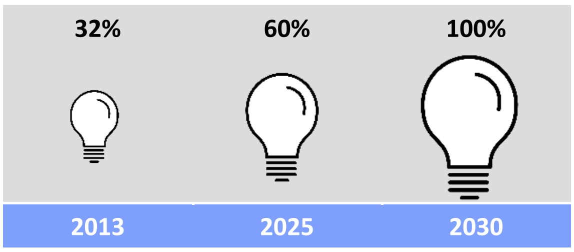


Figure 4: Target dates for access to electricity

To make up the shortfall, Nampower has entered into agreements with South Africa's Eskom for the supply of 200 MW, and with Zimbabwe Power Corporation and Zambia Electricity Supply Corporation. It also has Power Purchase Agreements (PPAs) with:

- 14 local renewable energy Independent Power Producers (IPPs), each generating 5 MW
- Greenam Energy to generate 20 MW of solar energy, which is expected to come on line in mid-2018
- Diaz Wind to generate 20 MW of wind energy.

Solar radiation, wind power, Kudu Gas and long-term coal resources have been identified by Cabinet as Namibia's major future energy sources.

NamPower has established a renewable energy unit and the Renewable Energy and Energy Efficiency Institute (REEEI) was established at the Polytechnic of Namibia (now the Namibia University of Science and Technology. Some 150 MW will be added to the grid by various solar, wind and biomass plants by 2018. The Ohorongo's cement factory will also be investing in a 5 MW solar PV plant, which will significantly reduce its electricity expenses and running costs.

The industry is divided into generation, transmission and distribution. Five Regional Electricity Distributors (REDs), of which only three are in operation, deliver power to the final consumer. They are Northern Namibia's Regional Electricity Distributor (NORED), Erongo Regional Electricity Distributor (Erongo RED), and Central North Electricity Distributor (CENORED). The establishment of the Southern Electricity Distributor (SORED) is imminent, leaving only Central RED to be established.

Oil and gas

The Kudu gas field, discovered by Chevron in 1974, has been estimated to contain in the range of 755–2 308 bcf of natural gas, which will feed into the Kudu Gas-to-Power Project, and will significantly reduce reliance on imported power.

The gas produced from the Kudu gas field will be transported through a 170 km pipeline to a planned power station that will be built at Uubvlei in the southern part of Namibia.

Namcor is mandated to ensure that the country has a steady supply of petroleum products. Liquid fuels are mainly imported through Walvis Bay and distributed by rail and road. An oil tanker jetty, a buffer pump station, petroleum pipelines and a 75 million litre oil-storage facility are being constructed to increase storage capacity.

Water and sanitation

In 2012, a total of 92% of the population had access to safe drinking water, made up of 98% of the urban population and 87% of the rural population. The same was not true of sanitation, where 32% of the population had access to improved sanitation, made up of 56% of the urban population and 17 % of the rural population.

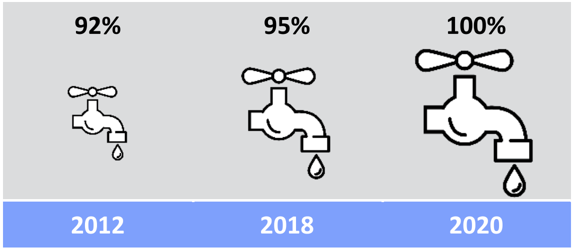


Figure 5: Target dates for access to safe drinking water

The only permanently flowing rivers lie on the country's northern and southern boundaries. All rivers that originate inside Namibia's borders are ephemeral. The lack of readily available freshwater in the interior remains the most important limiting factor for development.

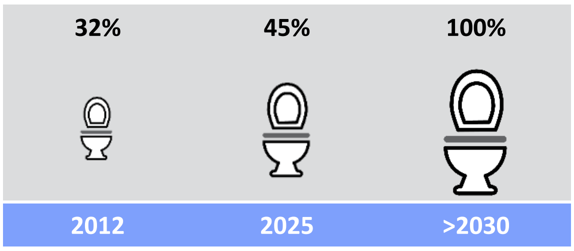


Figure 6: Targets for access to improved sanitation

The only bulk water supplier in Namibia is NamWater, which sells to municipalities who, in turn, deliver through reticulation networks to consumers. In rural areas, the Ministry of Agriculture, Water and Forestry oversees the potable water supply.

The main sources of supply water to Windhoek are surface water from the three dams, groundwater abstracted from 50+ municipal boreholes and reclaimed water recovered by suitable treatment. The municipality was the first in the world to recycle wastewater and is busy with the development of its third reclamation plant, which will treat industrial waste for irrigation. Windhoek also utilises a borehole-injection scheme that combines Aquifer Storage and Recovery (ASR) and Aquifer Storage Transfer and Recovery (ASTR). However, many aquifers are oversubscribed and are in imminent danger of drying up.

New water sources, such as desalination plants and long pipelines from new dams and boundary rivers, will be expensive to develop, but Namibia has committed to providing 100% of the population with potable water by 2020, as well as water reserves for industrialisation, land servicing and housing development purposes. This will include the construction of four desalination plants.

Namibia remains one of the countries with the lowest levels of adequate sanitation in southern Africa. The problem is particularly acute in the rural areas, which constitutes a serious public health risk to a large percentage of the population. NDP 5 has set targets of 40% of the population in rural areas and 87% in urban areas having access to adequate sanitation by 2025.

TRANSPORT AND COMMUNICATION

The regulation of road, rail, sea and air transport falls under the Ministry of Works and Transport. Namibia is currently developing plans to position itself as a regional hub for the import and export of goods to landlocked countries by means of the Walvis Bay Corridor Group (WBCG) initiative. Roads are the primary thoroughfares connecting towns and cities

Disclaimer:
Aurecon gives no warranty of any kind, expressed or implied, with regard to the map or data whether for its reliability, accuracy or completeness and shall not be held liable in any event for any loss or damage in connection with or arising out of the use of this data or map. The Client accepts all inherent limitations of the maps and data, including the fact that the maps and data are dynamic and in a constant state of maintenance, correction and revision. The data and map remain the sole property of the CLIENT and may be used for purposes of this Project with the prior written approval from the CLIENT. aurecon

Figure 7: Transport corridors

inside Namibia to its neighbours. Huge freight volumes move between Namibia and South Africa.

State-owned enterprises, TransNamib, Namport, Air Namibia and Namibia Airports Company (NAC) play a key role in Namibia's transport sector. The planning, building and maintaining of Namibia's road network are the responsibility of the Roads Authority (RA) and the Roads Contractor Company (RCC). The following corridors traverse Namibia:

- **The Trans-Kalahari Corridor (TKC)** which comprises a 1 900 km tarred road linking the port of Walvis Bay with Botswana and Gauteng, and the 1 500 km Trans-Kalahari railway line envisaged to connect Namibia and Botswana via the port of Walvis Bay and the existing railway line in eastern Botswana.
- **The Walvis Bay-Ndola-Lubumbashi Development Corridor (WBNLDC) (also known as the Trans-Caprivi Corridor)** which links the port of Walvis Bay with Zambia, the southern Democratic Republic of Congo (DRC) and Zimbabwe. The corridor consists of 2 500 km of road and a railway line between Walvis Bay and Grootfontein.
- **The Trans-Cunene Corridor** which links the port of Walvis Bay with southern Angola up to Lubango. The corridor consists of 1 600 km of road and railway line which extends from the port of Walvis Bay to Oshikango.
- **The Trans-Oranje Corridor** which consists of a tarred road from Walvis Bay and Lüderitz to the Northern Cape Province of South Africa and a railway line from the port of Lüderitz to the Northern Cape Province via Upington.

Investment in all modes of transportation – road, rail, maritime and aviation, will be required to support the concept of developing Namibia as a gateway to countries in the SADC region and beyond and maximise its potential to create jobs and grow the economy.

Roads

Namibia has 44 138 km of roads, of which 6 387 km are surfaced. The HPP expressed concern over Namibia's reliance on road networks for the transport of cargo, as overloading causes damage to the infrastructure, and heavy traffic presents road safety risks. Many roads are to be surfaced or upgraded as shown in Table 2.

Over the years, the RA has developed a sophisticated road maintenance and asset management system to monitor road condition and to plan and carry out maintenance in a systematic manner. However, due to resource constraints, the extent of the maintenance provided is no longer ideal. The RA has only four gravel replacement units (GRUs) countrywide whereas they require 14, and each has the capacity to cover only 120 km a year. These limitations have forced the RA to prioritise roads carrying higher volumes of traffic.

The RCC is engaged in the construction and maintenance of roads, as well as the development of land infrastructure related to civil engineering. The roads parastatal has been struggling to make ends meet and its future is in limbo as politicians are deciding whether or not to shut it down.

Rail

TransNamib owns the rolling stock but not the track. The network is owned by the Ministry of Works and Transport which pays for maintenance and extension through the budget. The rail network currently consists of 2 628 km of line.

Rail services play a critical role in the distribution of goods such as petrol and diesel, and mineral ores, and other goods between the port of Walvis Bay and the interior. Burdened with an ageing fleet and infrastructure, TransNamib has been plagued by delivery and reliability problems.

Projects under the HPP related to the railway network are shown in Table 2. Detailed feasibility plans for these projects were to be submitted for approval by Cabinet by March 2018. The most ambitious project is the 1 500 km Trans-Kalahari Railway which will transport 90 million tonnes of coal from Botswana per year. Although the Namibian and Botswanan governments committed to this project in 2014, there have been difficulties in attracting investors to form a Public-Private Partnership. The original rationale is under review and consideration is being given to creating a corridor equipped to transport a range of commodities and not just coal.

A study on the feasibility of introducing a high-speed train, to reduce congestion between Windhoek and Hosea Kutako Airport, Windhoek and Okahandja, Windhoek and Rehoboth, and Windhoek and the City Centre, has been concluded. The first phase of development will be to the Windhoek City Centre, but investors need to be found before the project can commence.

Ports

Namibia's two ports, Walvis Bay and Lüderitz, are managed by Namport. With direct access to principal shipping routes, Walvis Bay is a natural gateway for international trade. The next nine years will see the development of the SADC Gateway Terminal to serve as a regional sea transport hub.

HPP's Detailed Implementation Plan lists the completion of the deepening and expansion of the Port of Walvis Bay to be able to handle a minimum of one million TEUs (TEU refers to 20 ft equivalent unit, a unit of measurement of cargo capacity). The new container facility is expected to come into operation in 2019.

Airports

Hosea Kutako International Airport is the principal airport and the hub for international flights. It handles over 700 000 passengers and 14 000 flights a year. The Namibia Airports Company (NAC) manages all 21 major airports in Namibia. Hosea Kutako International Airport has exceeded its capacity and has had to develop strategies to manage the increased traffic movement to sustain slot allocation. There is, however, a need to develop the new passenger terminal.

Communications

The regulation of information technology and the telecommunication sector in Namibia falls under the Communications Regulatory Authority of Namibia (CRAN). The main operators are Telecom Namibia (fixed-line provider) and MTC (cellular provider). A third operator, TN Mobile, entered the market but was taken over by Telecom Namibia in 2012 so that it could add a cellular service to its offerings. MTC has some 1 088 base stations and Telecom Namibia has 409.

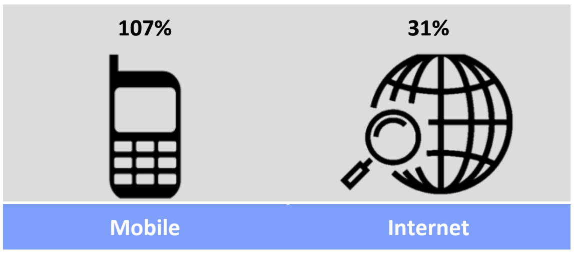


Figure 8: Percentage of population connected to services

Following the completion of the West African Cable System (WACS) landing point in Namibia, in May 2012, MTC introduced the 4G service in Windhoek.

Primary construction of a fibre-based network connecting regional capitals has been completed by Telecom Namibia. With approximately 12 000 km of fibre across the country, connectivity has reached 57 towns. Namibia is connected to two submarine fibre cables, WACS and African Coast to Europe (ACE), which enhances the reliability and performance of Namibia's connectivity to global communications.

NAMIBIA

In 2016, there were 2.66 million mobile device subscriptions, representing a 107% penetration rate, and 187 853 fixed-line telephone subscriptions, representing just 7.6% of the population. Internet penetration was only 31%. Fixed-line broadband utilisation covers only 2.6% of the population, and with the low rate of internet penetration and the high relative dependence on mobile connectivity, MTC has launched a R1.2 billion wireless network expansion project, dubbed 081 Every1, aimed at providing 100% wireless network coverage by 2019.

CONSTRUCTION

The construction sector is a significant contributor to employment and economic growth in Namibia and thus contributes to the GDP. Apart from the need to develop the energy, water services and transport sectors as discussed in the previous sections, the private sector is also busy with major developments.

Table 2 shows a list of public sector projects, but to this must be added the development of several malls and residential developments.

Of concern to the sector has been the recent trend of awarding many major projects to international contractors, side-lining local contractors and limiting local job creation prospects. This is contrary to the philosophy of the Growth at Home strategy. While foreign expertise and related financial capacity may be necessary for specialist mega projects, it is important that no foreign labour is involved in projects and that skills transfer takes place to build the capacity of the local industry. It is also important that Namibian-manufactured products are used where available. Large-scale projects must lead to employing those who are currently unemployed and who desperately need to secure an income.

In terms of quality and the recent trend of awarding projects to the lowest price bidder, even if they had the lowest technical score, it has been noticed that *'most roads constructed after Independence have an extremely high maintenance cost, compared to roads constructed before Independence'.*

The Reciprocal Investment and Protection Agreement signed in August 2005 between China and Namibia, although excellent from an investment and development point of view, has resulted in many Chinese firms and large numbers of Chinese employees entering the local market. Namibia is now home to 40 Chinese companies generating about US$5 billion in revenue per year, involved in large-scale projects, such as the building of harbours, railways and bridges. China's influence can be felt across Walvis Bay with Chinese utility vehicles and staff buses ferrying employees to and from the Port and the Husab Mine, where China's biggest investment aims to make Namibia the second-largest uranium producer in the world. Local labour and skills transfer need to be built into such contracts.

On a positive note, two Namibians have been awarded bursaries by Chec to study Marine Harbour Engineering in China with a view to returning to offer their expertise in and around the Port of Walvis Bay.

Table 2: Major projects identified, or being planned or under construction

PROJECT		VALUE US$	START YEAR	END YEAR
Energy	Angola–Namibia Interconnector	Feasibility		
	Kudu Gas Power Station (442.5 MW)	$9.4bn	TBD	
	Zimbabwe–Zambia–Botswana–Namibia Interconnector	$223m	2019	2021
Water	Neckertal Dam	$3.2bn		2018
Ports & airports	Rehabilitation of the Eros runway and completion of the VIP Terminal	$38.54m	2018	2020+
	Upgrade of the Hosea Kutako International Airport and runway to a Category 4F aerodrome	$9.61m	2019	2020+
	Surface Swakopmund–Henties Bay–Kamanjab road	$61.66m	2016	After HPP
	Upgrade of the Karibit–Usakos–Swakop road	$60.69m	2016	2020+
Roads	Upgrade of the Omuthiya to Ongewediva road to dual carriageway	$27.21bn	2017	2020+
	Upgrade of the Windhoek to Okahandja road to dual carriageway	$121.87m	2014	2019
	Upgrade of the Windhoek to Hosea Kutako International Airport road to dual carriageway	$64.89m	2016	2019
	Upgrading of the Swakopmund to Walvis Bay road to dual carriageway	$77.83m	2016	2019
	Introduction of a commuter train between Windhoek and Hosea Kutako International Airport	Unknown		
	Trans-Kalahari Railway (will take at least year 5 years to build)	$10bn	Funds to be raised	
Rail	Upgrading of the rail network from Walvis Bay to Tsumeb	Unknown	Tender	
	Upgrading of the Sandverhaar to Buhholzbrunn rail connection	Unknown	2019	2022

Housing

Urbanisation has continued to rise and Vision 2030 predicts that by 2030 the population in urban areas could be as high as 75%. If the trend of limited investment in infrastructure and associated maintenance continues, the infrastructure will be dilapidated and unreliable.

It is estimated that over half a million people, who constitute more than a quarter of the population, live in shacks in urban areas. The current average house price in the country is around N$800 000, which is unaffordable to 90% of the population. Namibia has a national housing backlog of over 300 000 units and with an urbanisation rate of 4.43%, demand for affordable housing will remain strong, for both rental and purchase.

The key challenge of housing delivery is the lack of available serviced land, which is both slowing down the process of delivery and pushing up prices. Due to the limited availability of serviced land, housing projects tend to be developed wherever land is available, rather than the projects being integrated with existing or future developments such as commercial and public amenities, e.g. shopping services and public parks/playgrounds.

LOCAL GOVERNMENT

Namibia is divided into 57 unitary local authorities comprising 13 municipalities, 26 towns and 18 village councils.

Councils are responsible for water and sanitation, roads and stormwater, waste management, environmental protection, electricity, building control, support services such as fleet (plant and equipment), economic promotion and tourism. With the introduction of the REDs, the responsibility for electricity provision has been taken over from those municipalities that fall within the jurisdiction of the REDs that are now operational. Municipalities are, however, still responsible for street lighting, traffic lights and electrification of amenities. It has been suggested that regional water boards should also be put in place to ensure adequate engineering capacity and cross-subsidisation between small and large municipalities.

Over the years, many engineering staff have left local government, to the detriment of the infrastructure, at a time when urbanisation is on the increase. In the large municipalities, it is a requirement that the heads of engineering departments are registered professional engineers and their immediate subordinates must also be registered engineering professionals. It is, however, not a requirement for technicians to be registered.

Ageing infrastructure, urbanisation, densification, financial constraints and, at times, political interference are challenges faced.

Most small municipalities have only one engineering technician in their employ, citing budgetary constraints as the main reason for removing engineers from the organogram. Maintenance is carried out on an ad hoc basis.

Given the fact that it costs significantly more to repair infrastructure than to maintain it, the short-term savings will result in long-term costs for these municipalities, as they no longer have the capacity to adequately plan, develop, operate and maintain their infrastructure.

The challenge, however, is the worsening economy, with fewer and fewer people being able to pay for services, and as they deteriorate, even those who can afford to pay are not prepared to pay for a reduced service.

EDUCATION, TRAINING AND PROFESSIONAL DEVELOPMENT

Education and training is a vital part of developing engineering capacity. All elements, from teaching appropriate subjects at schools to continuing professional development (CPD), need to be in place to educate, train and ensure that engineering personnel remain abreast of the latest technology, challenges and emerging solutions.

Key concerns in Namibia include access to quality early childhood development, vocational training opportunities and the mismatch between the supply of and demand for skilled labour.

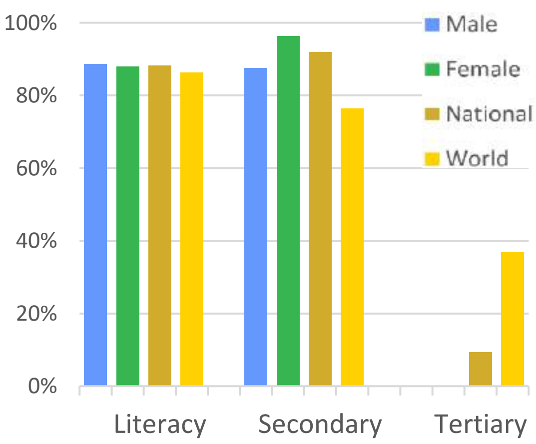


Figure 9: Literacy and enrolment statistics

(Secondary covers only lower secondary)

(UNESCO 2015 to 2016)

NAMIBIA

PRIMARY AND SECONDARY EDUCATION

Compulsory education in Namibia starts with primary education which consists of seven years from Grade 1 to Grade 7. Secondary education stretches over five years from Grade 8 to Grade 12. Education in Namibia suffers many challenges, including crowded classrooms and unqualified teachers. Declining employment conditions and benefits have led to a limited pool of dedicated teachers, most of whom teach in private schools, which offer better conditions.

Of concern is the quality of infrastructure. More than 20% of schools have no toilets or water supply and few have air-conditioners or heaters, making learning difficult in the extremes of heat and cold suffered in desert climates. Many buildings are in a state of disrepair and leak in rainy conditions. Furthermore, with no communication between schools and the outside world it is difficult to coordinate the provision of supplies and services to schools and learners. Following the needs analysis in Towards Education for All, a new curriculum was formulated in which automatic promotion was introduced. The policy stipulates that a learner is only allowed to repeat once in each school phase, which is of great concern in terms of the quality of outcomes.

There is a shortage of mathematics and science teachers. In 2012, only 278 of the 15 502 learners writing the senior certificate exams passed higher grade mathematics with a symbol of 1 or 2, which is required for entrance into engineering degrees.

HIGHER EDUCATION

Namibia has two public tertiary institutions, the University of Namibia (UNAM) established in 1992, and the Namibia University of Science and Technology (NUST).

NUST was transformed from the Polytechnic of Namibia (PON) at the beginning of 2016. The Polytechnic was initially formed as a consolidation of the College of Out-of-School Training (COST) and Technikon Namibia in 1994. NUST offered national diploma and BTech qualifications and has, since 2013, offered professional engineering degrees. As of 2016, it has added Industrial Engineering to its range of qualifications, hence NQ (for None qualified) in Table 3. The move to degrees, and dropping some technician qualifications, is a concern, as the country still needs an ongoing supply of technicians.

Just over 11% of students in the engineering faculty are foreign, with two-thirds coming from neighbours – Angola and Botswana. NUST reports having difficulty in attracting sufficient teaching staff, with 40 vacancies out of a total of 90 posts. Just over half those currently employed are foreigners.

UNAM, whose engineering campus is based in Ongwediva, had a total academic complement of 39 in 2012. A total of 60 students graduated with engineering degrees in 2015, as can be seen in Table 3. Forty-four per cent of academics and 31% of students in the engineering and IT faculty were foreign. Of interest is the fact that of the 2 893 students in total who graduated, only 10% were foreign, indicating the demand for engineering education from neighbouring states.

In time, Marine Engineering and Maritime Studies will be offered in a dedicated training centre in Walvis Bay, hence NQ (for None qualified) in Table 3.

UNAM also reports academic vacancies, despite relying heavily on foreign teaching staff. The problem of low salaries has been cited as the main reason for not being able to attract adequate teaching capacity.

Table 3: Engineering graduations in Namibia in 2015

INSTITUTION	QUALIFICATION	Civil & Environmental	Electrical, Electronics & ICT	Industrial	Marine & Maritime	Mechanical	Mining & Metallurgy
University of Namibia (UNAM)	BSc (Hons)	15	15		NQ	5	20
Namibia University of Science and Technology (NUST)	BEng	18	11	NQ		3	12
	BTech	24	38			21	
	ND	46					
TOTAL							
Engineer (99)		33	26			8	32
Incorporated Engineer (83)		24	38			21	
Technician (46)		46					

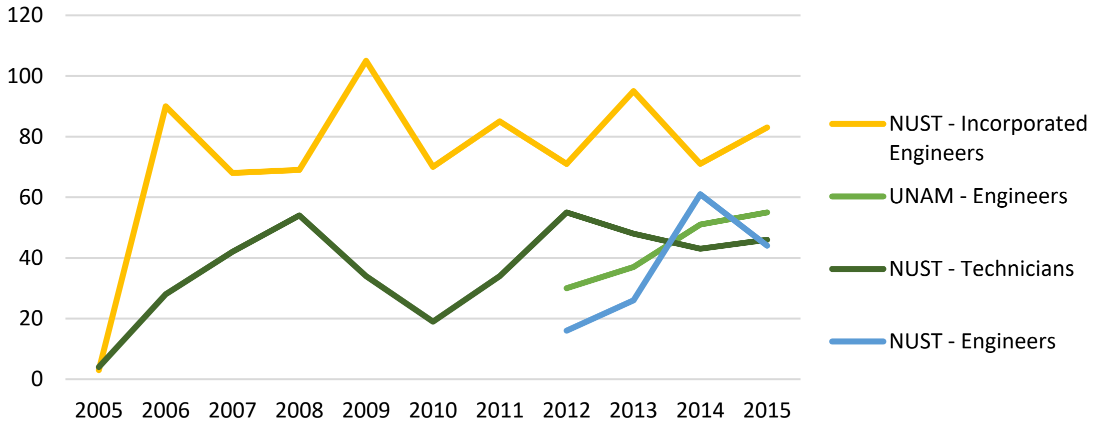


Figure 10: Engineering graduates by institution and category

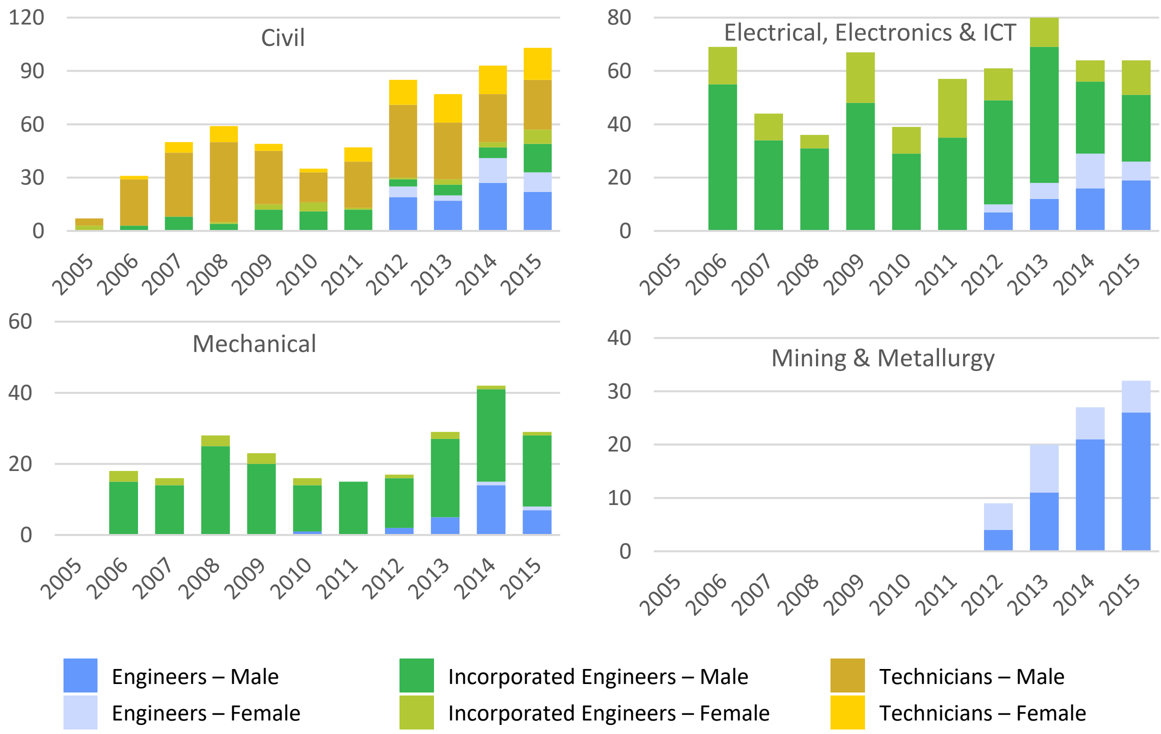


Figure 11: Engineering graduates by discipline, category and gender

The graduation statistics split by institution and category are shown in Figure 10 and by discipline, category and gender in Figure 11. It should be noted that in Namibia, the BTech is a post-graduate qualification to the national diploma. Graduates with a BTech are known as incorporated engineers but are not included in the workforce projections as they would have already been recorded in the workforce as technicians.

Accreditation

The Namibia Qualifications Authority (NQA), with the help of Engineering Council of Namibia (ECN), accredits the engineering qualifications.

The ECN uses the guidelines set by the International Engineering Alliance (IEA) to determine criteria for the recognition of engineering qualifications and competence required for professional registration. Although the programmes of the UNAM and NUST are not yet recognised by the IEA, the ECN recognises engineering qualifications from both universities.

Both institutions have approached the Engineering Council of South Africa (ECSA) to assist them with assessing their qualifications and advising on the requirements for Washington Accord accreditation. ECSA has carried out assessments and has highlighted shortcomings, the most important of which is the shortage of full-time academics. Both institutions are assisting their young academics to complete post-graduate qualifications, many outside the country, in order to fill the gaps, and are confident that they will achieve the Washington Accord requirements in the coming years.

Student Mobility

In 2015, there were a total of 6 256 Namibians studying at South African universities, of whom 1 488 were studying by correspondence, through the University of South Africa. The largest number, 2 497, were studying at North West University. A total of 81 engineering students graduated – 28 completing degrees, 38 completing BTechs and 15 completing national diplomas. Studying outside of Namibia is not unusual and was commonplace prior to the introduction of engineering degrees in the country. Eighty-nine per cent of all Namibian professionals 40 years and older who were registered with the ECN in 2016 studied outside the country, 75% of whom had studied in South Africa.

In the group under 40 years old, some 56% of Namibians have studied outside the country, with 47% having studied in South Africa, 3% in Russia, 2% in Cuba, 1% each in Germany and Zimbabwe, and smaller numbers in countries such as Austria, the UK, Botswana, Cyprus and Tanzania, among others.

As higher education capacity is still limited, the government supports many students to study engineering overseas. The government pays the travel and accommodation costs, while host countries offer free engineering education at selected higher education institutions. A challenge faced by returning graduates is that some foreign qualifications are not recognised as being on par with local qualifications; this means that they are unable to register as graduates-in-training with the ECN, which is a requirement before getting a job, and they struggle to find employment.

The Ministry of Education needs to ensure that the international engineering qualifications for which they are offering sponsorships do indeed address the needs of the country. Collaboration with the ECN is essential. As an alternative approach, UNAM and NUST engineering faculties should be funded to increase their capacity and resourcing, in order to increase the numbers graduating locally.

Just under 10% of engineering students studying in Namibia are foreign nationals, with Angolans making up half this number, followed by Batswana. Students from six other SADC countries, and Kenya and Uganda, make up most of the balance.

GRADUATE TRAINING

Once the tertiary education phase is complete, it is necessary for graduates to receive structured training in the workplace, under professional supervision and mentorship, to develop to the level of competence required for professional registration, and to be able to take on work independently.

In the private sector, training and mentoring of graduates is done by firms at their own cost, since there are no rewards or tax breaks for developing professionals. The 2017 President of the Association of Consulting Engineers of Namibia (ACEN) advised that employment opportunities for graduates were so dire that graduates were offering to work without pay to gain experience.

In the public sector, although training programmes are still in place in the utilities, the lack of experienced engineering staff to act as coaches and mentors presents a problem. The type of work is no longer conducive to exposing graduates to the range of experience necessary to develop as professionals, as most planning and all design work is outsourced. Junior engineering public servants complain of not being able to progress in their careers. Sadly, when they are seconded to the private sector on projects, it is generally only at the implementation stage, rather than planning and design.

Agreements between the government and international investors usually have skills transfer as a condition, but often these conditions are not effective or managed properly, thus do not result in competent engineers having been trained by expatriates. Training is often superficial and when foreign experts leave the country, the projects collapse.

There is an urgent need to consider the plight of graduates and provide structured, funded training to develop the professionals of tomorrow. In the words of the President of the Namibian Society of Engineers (NASE), Mr Mukwaso, '*Government is paying millions in tuition fees for engineering students, yet it is not providing an environment for those students to practise once they complete their studies and enter the job market'*. It is estimated that there are some 67 000 unemployed graduates in Namibia, including engineering graduates who have studied both locally and abroad.

On a positive note, the mining sector offers structured graduate programmes and absorbs many graduates from UNAM.

PROFESSIONAL REGISTRATION

The publication of the Professional Engineers' Act, No. 81 of 1968, was the beginning of professional registration in Namibia, requiring registration of engineers and engineers-in-training. This was replaced by the Engineering Profession Act, No. 18 of 1986 as amended in 1991, which is administered by the Ministry of Works and Transport. The new Act and the amendment extended the scope to cover the registration of professional engineers, incorporated engineers (known as technologists in this study), engineering technicians and the associated categories in training.

The ECN is the regulatory body responsible for managing registration of the engineering profession in Namibia. In 2016 there were 1 779 registered members, as shown in Table 4, 809 professionals and 970 graduates-in-training.

Before graduates can apply for work they must be registered as graduates-in-training with the ECN. Registration requires that they hold an engineering qualification that is recognised by the ECN. When a candidate is working as a graduate-in-training it is necessary for him or her to work under the supervision of a registered professional.

During 2017 and 2018 the ECN faced several challenges. In 2017, it was found that the President was not a registered engineering professional, as required by the Act, which was concerning to those being assessed by the Council. Once the 2013–2017 Council term ended, it took some 16 months to appoint a new Council, during which time registrations could not take place, much to the frustration of those aspiring to become registered professionals. The new Council was finally appointed on 26 June 2018, with Dr Smita, who holds a Doctorate in Electrical Engineering, installed as its first female president.

A further challenge is the recognition of foreign qualifications. Many foreign qualifications earned by those studying abroad have been found not to meet the requirements set by the ECN, using the Washington, Sydney and Dublin Accords graduate attributes as a guideline. This is a point of contestation, as graduates with foreign qualifications are unable to apply for engineering jobs if they are not registered with the ECN as graduates-in-training. It would seem that the ECN assessment should include guidance on the category of registration for which applicants may qualify to allow them to register as graduates in the appropriate category. Further, the ECN should suggest additional subjects that would be necessary to enhance their qualifications to the category for which they applied.

Table 4: Members registered with the ECN as at October 2016

CATEGORY OF REGISTRATION	NUMBER
Professional Engineers (Pr. Eng.)	506
Engineers in Training	452
Incorporated Engineers (Inc. Eng.)	201
Incorporated Engineers in Training	321
Engineering Technicians (Eng. Tech.)	102
Engineering Technicians in Training	197
TOTAL	**1 779**

In reviewing the Act, the Council needs to address the recognition of foreign qualifications and the recognition of prior learning. The need for professionals to keep up to date is also important, the requirement for CPD should also be incorporated.

The ECN should also make the call for structured, funded graduate training to be introduced and for the public sector to employ the many Namibian engineering professionals who are unemployed, rather than foreign nationals.

VOLUNTARY ASSOCIATIONS AND CONTINUING PROFESSIONAL DEVELOPMENT (CPD)

Although this is not called for in the Act, it has been recognised that engineering professionals need to keep abreast of the latest technology and legislation, and should continue to advance their knowledge.

The Engineering Professions Association of Namibia (EPA) is a non-profit, voluntary membership association of engineering and related professionals, which strives to uphold excellence in the field of engineering by promoting the image of the profession and the continuing education and common interests of its members. It promotes the profession at schools, hosts school competitions, acts as the voice of engineering to the government and the public, and organises many seminars, courses, workshops etc. to keep its members up to date.

The EPA's membership is made up largely of private sector members, almost 60% of whom are civil, just over 20% electrical and 18% mechanical engineers. The balance are made up of a handful of agricultural, chemical, industrial, mining and marine engineers.

The second voluntary association, known as the Namibian Society of Engineers (NASE), was formed in November 2016. Working alongside Engineers Without Borders Namibia, NASE aims to support and promote local professionals, engineering graduates and aspiring engineers, and address challenges facing the industry and the country. NASE has been very active since its inception and has enlisted the help of the country's founding President, H.E. Dr Sam Nujoma, to support the association in its activities.

WOMEN IN ENGINEERING

Namibian Women in Engineering (NAMWIE) has been set up as a voluntary association for women engineers to promote the profession, engage with fellow female engineers and support women growing as engineering professionals.

THE WORKFORCE

It is estimated that there are about 2 800 engineering practitioners in Namibia, with an age and gender distribution as shown in Figure 12.

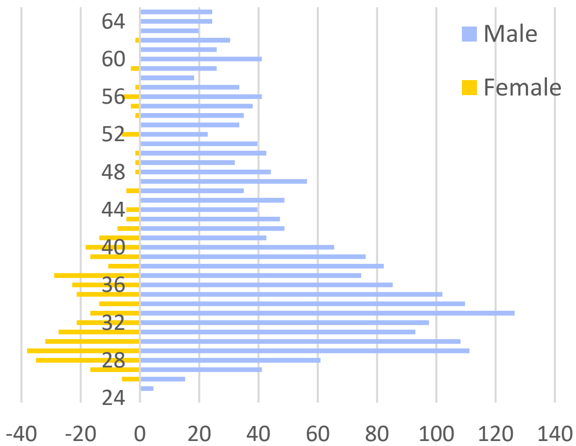


Figure 12: Engineering practitioners by age and gender, 2017, based on ECN data

THE PRIVATE SECTOR

The main employers in the private sector are consulting, contracting, manufacturing, supplier and mining companies. Lower numbers are employed in small entrepreneurial companies, NGOs, training organisations and other companies where engineering input is required.

In 2013, some 48 000 people were employed in the construction sector, representing consultants, contractors and construction material manufacturers and suppliers.

Consulting

The Association of Consulting Engineers of Namibia (ACEN) is a voluntary association of consulting engineering firms, whose aim is to represent the interests of members to clients and vice versa, and to provide guidance to consulting firms on best business and consulting practices. In the 2017/2018 financial year it recorded a membership of 60 companies, employing 447 engineering professionals (down from 637 in the 2014/2015 year). Input received from consulting companies indicates that they employ a further 15–20% who are not registered with the ECN.

It is estimated that there are some 30 consulting firms who are not ACEN members working in specialist fields, adding about 30 to 60 professionals to the ranks of consulting.

In 2014, consulting firms were lamenting the shortage of experienced staff and advised that they needed to work long hours to cope with the workload. However, by 2017, with the slowdown in the economy and the dominance of international service providers, ACEN members reported the need to retrench 101 staff in order to survive. Traditionally, many consulting firms have offered bursaries and assisted emerging professionals with skills development, but with the poor economic conditions this support has reduced.

Although calls are made for the private sector to offer training, it is also necessary for companies to bid for all their work. With the shortage of work, prices have been driven to such low levels that concerns have been expressed about the adequacy of final solutions and the quality of work. No margins remain to invest in training. The recommended fee scales should be considered when selecting service providers to ensure a comprehensive service.

Where consulting firms are appointed to oversee the work of international service providers, the use of the FIDIC Conditions of Contract is appropriate, as this is an international suite of documents, covering the range of engineering project types. Engineers are concerned that the government wishes to impose the use of General Conditions of Contract (GCC) on all projects, which will not cover all types of work. An engagement in this regard is required.

Contracting

Infrastructure development depends on the health of the construction sector. The sector is represented by the 450-member strong Construction Industries Federation of Namibia (CIF) which is the national voice of the construction sector but has no regulatory functions. CIF membership categories for contracting members are shown in Table 5. There are similar categories for Trade Members and Affiliated Members.

In 2012 there were 388 professionals and 745 technicians and managers in the sector. Assuming one-third of these to be engineering professionals and technicians (allowing for the rest to be in financial, legal, health and safety, HR, IT, quantity surveying and project and construction management posts) gives a total of 378 engineering practitioners.

The CIF conducts annual surveys and input received shows that there is a need to protect and regulate the industry and to establish a National Construction Council. This would ensure that every business operating in the industry would be licensed and that the size of the company is linked to the size of the project when awarding contracts. Almost 70% of the respondents to the survey in 2017 highlighted that Asian contractors dominated the sector.

With government spending cuts, this is a problem as insufficient projects are being awarded to local contractors for their survival. There is a tendency to think that the construction sector in Namibia is not able to take on big projects as they do not have the capacity and machinery. This is not the case. A worrying 83% felt that the long-term sustainability of the Namibian construction industry was threatened by competition arising from non-Namibian contractors, and stated that Namibian construction companies do indeed have the capacity and appropriate infrastructure to handle large-scale projects. Should they not be engaged as the main contractor, they should at least be appointed as subcontractors or partners in larger projects.

Of the 122 responses received to the 2017 survey, 43 respondents (34%) stated that they would either have to close their businesses or have to declare bankruptcy, and a further 49 respondents (40%) stated that they would have to scale down their businesses drastically or become dormant.

The Namibia Small Contractors Association represents the interests of SMMEs in the construction sector.

Table 5: Categories of contractors belonging to the CIF

CATEGORY	TURNOVER N$	NUMBER OF MEMBER COMPANIES
A	>200m	7
B	≥100–<200m	8
C	≥50–<100m	8
D	≥20–<50m	28
E	≥10–<20m	32
F	≥5–<10m	25
G	≥2–<5m	18
H	<2m	29

Manufacturing

A Ministry of Trade and Industry report in 2003 stated that there are 384 manufacturing companies. This would exclude many SMMEs covering the range of manufacturing activities. In 2013, the sector employed about 32 800 people.

Manufacturing companies are represented by the Namibia Chamber of Commerce and Industry, and the Namibia Manufacturing Association (NMA). The NMA aims to be the voice of manufacturing and works hard to represent members' interests. It plays an important role in influencing the formulation of policies affecting manufacturers, such as manufacturing incentives, work permits, taxation, NDP 4/NDP 5, Growth at Home, the HPP, the New Procurement Bill, etc.

In 2012, there were 708 professionals and 1031 technicians and managers in the sector. Assuming 25% of these to be engineering professionals and technicians (allowing for the rest to be financial, legal, health and safety, HR, IT, project management and scientific posts) gives a total of 435 engineering practitioners. At the time it was projected that 780 would be required by 2015. Many reports have highlighted the need for more mechanical and electrical engineers and a demand for 100 production managers was highlighted. The introduction of industrial engineering at NUST will address this in time.

Mining

There are 17 major mining companies. In 2013 the sector employed about 13 600 people. The mining industry complains of the shortage of technical skills. In the 2014 Mining and Quarrying Sector Skills Plan (SSP), a need for 400 more engineers and technicians was suggested.

At the time a total of 1 538 professionals and technicians were employed in the sector.Assuming 25% of these to be engineering professionals and technicians (allowing for the rest to be in financial, legal, health and safety, HR, IT, project management and scientific posts) gives a total of 383 engineering practitioners. Over the past few years this will have increased with new mine developments, but by 2018 the numbers are unlikely to be any higher than 450. The sector plan complains of the low number of graduations from UNAM and NUST.

THE PUBLIC SECTOR

Many engineering practitioners are required in the public sector, including in municipalities, to plan new services, issue project tenders and oversee the delivery of, and operate and maintain, infrastructure.

NAMIBIA

Table 6 shows the departments that are the main employers of engineering skills.

A study on the role of the engineering profession in Namibia, undertaken in 2014, found that there were acute shortages of engineers in all tiers of government. Not only were there shortages, but experienced engineers had been replaced with junior technicians who had insufficient training and experience to lead major developments or operate and maintain infrastructure. In many cases, non-technical staff have taken over decision-making in engineering departments, without consultation and/or against advice provided.

Infrastructure departments are responsible for the implementation, management and maintenance of major projects and should be managed by highly skilled technical engineering managers. Poor salaries and an environment not conducive to technical decision-making and leadership have been cited as factors contributing to the reduction in technical staff in the public sector. More recently, a moratorium has been placed on employment in the public sector, resulting in a continuing reduction as technical staff leave and may not be replaced.

Table 6: Ministries employing engineering practitioners

MINISTRY/STRUCTURE
Ministry of Agriculture, Water and Forestry • Namibian Agronomic Board • Namibia Water Corporation (NamWater) • Directorate Water Resources Management
Ministry of Defence • Windhoeker Maschinenfabrik
Ministry of Environment and Tourism
Ministry of Fisheries and Marine Resources
Ministry of Industrialisation, Trade and SME Development • Namibia Development Corporation • Namibia Standards Institution (NSI)
Ministry of Information and Communication Technology • Telecom Namibia • Mobile Telecommunication (MTC) • Namibia Broadcasting Corporation • Namibia Post
Ministry of Mines and Energy • Epangelo Mining Company • National Petroleum Corporation of Namibia (NAMCOR) • Electricity Control Board (ECB) • NAMPOWER • CENORED • Erongo RED • NORED
Ministry of Public Enterprises • National Housing Enterprises (NHE) • Namibia Diamond Mining Corporation (Namdeb)
Ministry of Urban and Rural Development
Ministry of Works and Transport (MWT) • Air Namibia • Roads Authority (RA) • Roads Contractor Company (RCC) • Namibia Airports Company (NAC) • National Port Authority (NamPort) • TransNamib Holdings Ltd

Rigorous research carried out by the EPA in 2013 yielded a number of around 450 registered engineering professionals in the public sector, including the utilities and local government. Returns from the current research indicate that the number of registered professionals may have dropped, but the overall number of engineering practitioners is higher, considering those employed who are not registered.

The government is finalising a Recruitment and Selection Policy which will give them more say in the appointments made by local authorities and utilities to avoid interference by politicians, boards etc.

MIGRATION TRENDS

Analysis of the United Nations Population Division statistics for 2015 shows a net loss of professionals from Namibia. Of those entering the country, most were from Angola. Ninety per cent of professional emigrants moved to South Africa.

The exit of foreign professionals is likely to continue as many reach retirement age. As seen in Figure 13, a large percentage of currently registered professionals are foreign nationals. There is a need to develop a cohort of Namibian professionals to take over in time.

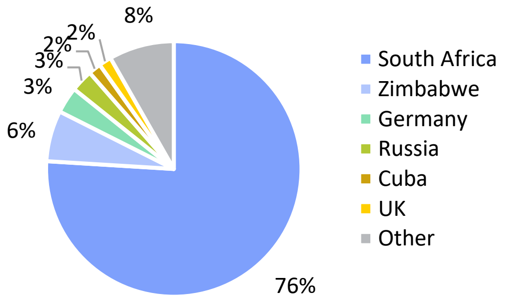


Figure 13: Nationalities of foreign engineering professionals registered with the ECN
(73.1% foreign or dual-nationalities)

ENGINEERING NUMBERS AND NEEDS

Combining all the data, it is estimated that there are 2 800 engineering practitioners in Namibia, as shown in Table 7. Considering all the developments planned, there is clearly a need for more qualified and well-experienced engineering practitioners. In 2015, 228 graduated from NUST and UNAM, and a further 43 engineers and technicians from South African universities, making the total 271.

Allowing for at least 100 graduates returning from studying outside the country, would suggest that about 371 were seeking employment. It should be noted that BTech graduates are not counted in those entering the workforce as they are already qualified and employed as technicians, while completing their BTech studies part-time.

Table 7: Estimated numbers of engineering practitioners in the engineering workforce

SECTOR	ESTIMATED NUMBER
Academia and research	150
Agriculture	50
Consulting	500
Contracting	400
Government incl. municipal	650
ICT, systems and telecommunications	60
Manufacturers and suppliers	450
Mining	400
Miscellaneous and NGOs	140
TOTAL	**2 800**

Figure 14 shows the current engineering workforce, the losses that will occur over the 18-year period to 2035 due to retirement, mobility and mortality, and the growth in engineering capacity if local engineering graduations increase at 2% per year over the period. This also includes an increase from 2020 as graduates from the new qualifications come into the workforce.

The blue dotted line shows the growth in skills that would be required at the 2017 GDP growth rate of - 0.8%% and the green dotted line shows the growth based on the 2018–2023 GDP projection of 3%. A 70% employment elasticity factor has been used to extrapolate the employment demand.*1

The target of 5 000 set by Vision 2030 will be achieved by 2028 if the demand remains static. However, if the demand increases as the projected growth rate of 3% this will move out to 2033. To achieve the increased numbers commitment will be required to start filling posts immediately and investing in graduates to ensure that they develop the competence required to assist with the current workload.

Should large-scale appointments not take place and the 3% growth rate continues, the number of graduates will substantially exceed the demand. Only if Agenda 2063 growth rates can be achieved, will the rate of graduation more or less match the demand. However, the ratio of graduates to experienced personnel will be high and large national, structured and funded workplace training programmes will be necessary to develop graduates in the first two to three years after graduation.

Should the country achieve the Agenda 2063 growth trajectory and plan to increase graduations further, consideration should be given to the following:

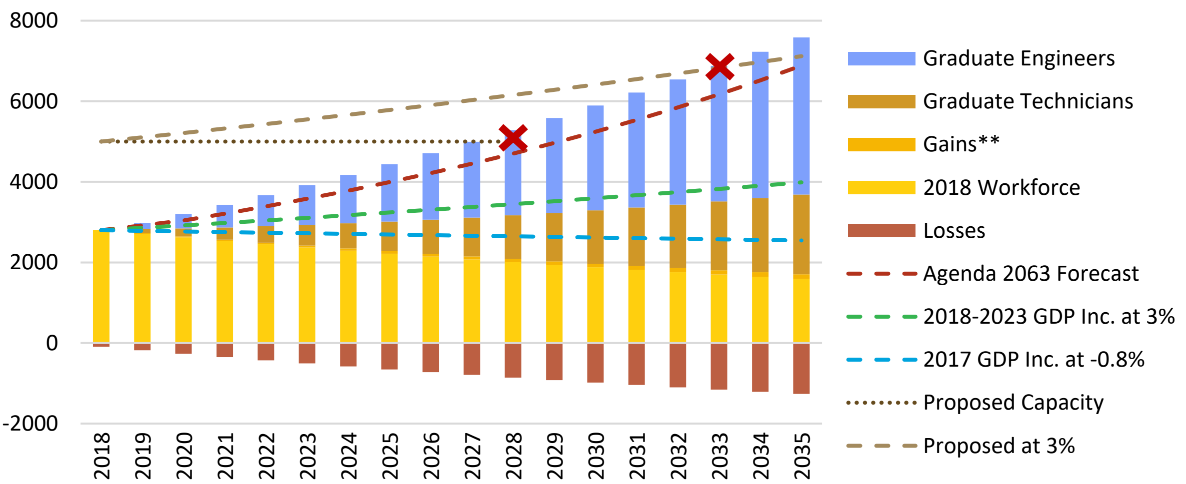


Figure 14: Flow of engineering skills based on a 2% increase in graduation rate per year

***Excludes international engineering practitioners in the country and not registered with the ECN. Those registered with the ECN are included in the workforce.*

---

*1 Employment elasticity is a measure of the percentage change in employment associated with a 1% change in economic growth. If the growth is likely to be in agriculture, the percentage could be lower, as growth in that sector is generally has to do with productivity gains and not employment, while if the growth is likely to be in high-tech manufacturing, the elasticity factor maybe more than 100%.

- **Agricultural engineering:** No agricultural engineering qualifications are offered in Namibia. To address the need for increased irrigation, mechanisation and post-harvest services, the government should consider making a few bursaries available each year for students to study outside the country.
- **Chemical engineering:** No chemical engineering qualifications have been offered in Namibia in the past. Chemical engineers and technicians are critical in the agro-processing sector, in biomass power generation, the oil and gas fields, desalination, water and wastewater treatment and recycling. NUST will start offering chemical engineering in 2019.
- **Civil engineering:** Due to the slowdown in construction spending and the use of international rather than local practitioners, there appears to be an excessive number of civil engineering graduates. This has given rise to the unemployed graduate phenomenon. Rationalisation of international studies, including the numbers, qualifications and institutions selected is required and the development and use of local practitioners should be supported.
- **Electronics and telecommunications:** With the growth of telecommunications, the emergence of the internet of things and the move to increased automation, more students need to be encouraged to enrol.
- **Industrial engineering:** Students need to be encouraged to enrol in the new industrial engineering course offered by NUST as graduates will ultimately play a significant role in terms of improved production and streamlining systems in the manufacturing and public sectors among others.
- **Marine engineering:** Since Namibia relies on so many resources from the sea – fishing, diamonds and gas, among others – the need for a marine engineering degree has been recognised. Once in place, students will need to be encouraged to pursue this career.
- **Mechanical engineering:** There are major roles for mechanical engineering practitioners to play in the manufacturing, power generation and mining sectors, and numbers need to increase.
- **Mining engineering and metallurgy:** With the growth of the mining industry, mining engineers and metallurgists are key to productivity and quality output, and the current rate of graduations should be maintained.
- **Specialisation**
  - **Geotechnical engineering:** A commonly heard concern was the lack of geotechnical expertise. Consideration should be given to offering bursaries for a few students a year to pursue further studies in this field, outside the country.
  - **Railway engineering:** With the planned upgrading and expansion of the rail network, railway engineering expertise will be required. Consideration should be given to offering bursaries for a few students a year to complete Master's degrees, outside the country. Alternatively, once the Railway Engineering degree offered by Instituto Superior de Transportes e Comunicações (ISUTC) in Mozambique is offered in English, a few students should be sponsored to complete the qualification and should be offered workplace training in a rail office with sufficient expertise to coach and ensure skills transfer.
- **Technicians:** The number of technicians qualifying is low relative to the number of engineers, and they are limited to civil engineering. Consideration needs to be given to training electrical, mechanical and mining technicians, as highlighted in the various Sector Skills Plans developed by the National Training Authority in 2014. Industrial attachment and the use of the latest technology should be key elements of such training.

KEY RECOMMENDATIONS

To develop a sound pool of engineering professionals, able to contribute to the well-being of Namibia, the following should be considered:

Schooling

- **Primary and secondary education:** Strengthen primary and secondary school education and address the teaching of mathematics.
- **Career guidance:** Expand career guidance to attract high-calibre entrants into the engineering profession, incorporating programmes to reach female learners, and rural and low-income areas.
- **Bursaries:** Provide bursaries to attract those who excel in mathematics and science to study engineering.
- **Studies outside the country:** Offer bursaries for students to study agricultural engineering outside the country as required and ensure that international institutions selected offer qualifications that will be

recognised by the ECN. The numbers should be based on demand from industry and public sector structures.

Tertiary education

- **Accreditation:** The ECN to develop a rigorous accreditation programme to ensure the quality of engineering education using the guidelines of the Washington, Sydney and Dublin Accords.
    - Support the efforts of UNAM and NUST to meet the requirements of the Accords and consider expanding the capacity of the local faculties to limit the number of who students who need to study outside the country.
- **Industry liaison:** Liaise with industry on a regular basis to ensure that curricula, methods, software and equipment are relevant and up to date and that numbers being trained match the demand.
    - Determine the demand for electrical, mechanical and mining technicians and offer qualifications required.
- **Curricula:** Provide funding to research, modernise or develop curricula and material where required.
- **Facilities:** Raise funding to upgrade lecture theatres, libraries and laboratory facilities where required.
- **Resources:** Raise funding for computers, engineering software, access to online reference material, and laboratory and other equipment, and ensure adequate support to offer technology-relevant training.
- **Attract and retain academics:** Improve conditions of service, support and packages to attract, retain and appoint additional academics.
- **Teaching methods:** Apply the latest methods and technology for teaching, and train academics in 21st century approaches to teaching.
- **Academic development:** Provide funding for lecturer post-graduate development and facilitate opportunities for academics to gain experience in industry.

Graduate training

- **Develop programmes:** Develop national graduate training programmes to ensure graduates achieve the level of competence required by industry and for professional registration.
- **Private sector incentives:** Offer incentives for private sector companies to develop graduates.
- **Public sector support:** Ensure that public sector structures take on and train graduates and that they are absorbed and developed through the ranks.
- **Institutional support:** Institutionalise graduate training in all organisations by setting KPIs for experienced staff to act as supervisors and mentors.
- **Project support:** Make graduate training a requirement of all public sector projects and ensure that the progress of graduates is monitored, and penalties are imposed for non-compliance.

Registration of engineering professionals

- **Registration:** Update the Engineering Professionals Bill to include continuing professional development, and recognition of prior learning.
- **Foreign qualifications:** Streamline the process of assessing foreign qualifications and sensitise government departments on the need to check the suitability of foreign institutions and associated qualifications with the ECN.
- **VAs:** Recognise and support the development of voluntary associations in the engineering sector.

Continuing development

- **CPD:** Support the development of a robust CPD system, monitored by the ECN but rolled out by the voluntary associations and higher education institutions, to include courses, workshops, conferences, online learning etc.
- **Validation:** Validate short courses and skills programmes for a specified period only to ensure that training remains up to date and relevant.
- **Post-graduate studies:** Provide post-graduate bursaries to develop specialists.
- **Develop managers and leaders:** Encourage industry to continue investing in graduates after professional registration to grow management and leadership capabilities.

Registration of service providers

- **Legislation:** Develop and adopt a a National Construction Industry Act to:
    - Cover the increasing the use of local consultants, contractors, labour, plant and materials.
    - Ensure that foreign consultants and contractors partner with local companies.
    - Ensure that there are requirements for consultants and contractors to train graduates, artisans and other construction-related skills.
    - Ensure that local consultants and contractors are developed as part of large projects.
    - Limit companies to a certain size or category of work based on their technical skills, past experience

and the availability of plant and capital.
    - Ensure that international consultants provide all calculations, drawings, operating manuals and other reference material in English.
    - Ensure that local consultants, along with the client, check that design proposals address local needs and customs and that design calculations comply with national codes and standards.
- **Quality:** Implement quality assurance on all projects and ensure penalties are imposed for poor performance.

The public sector

- **Economic infrastructure:** Invest in the development of economic infrastructure such as electricity, roads, rail and airports, and address the supply of water services.
- **Maintenance:** Invest in maintenance to preserve new infrastructure and prevent further deterioration of existing infrastructure.
- **Tariffs and payment:** Review and increase tariffs where appropriate, and enhance domestic revenue collection and demand management to fund development.
- **Technical capacity:** Reprioritise budgets to fill vacant posts and build technical capacity, ensure that salaries are competitive and develop succession plans to make the public sector an employer of choice.
- **Technical decision-makers:** Ensure that engineering professionals are employed in senior decision-making posts.

Industry-wide collaboration

- **Advisory team:** Set up an engineering advisory team, recognised by government, to advise on and endorse infrastructure development proposals, tertiary curricula and graduate training programmes.
- **Collaboration:** Encourage all professional bodies to work together to share knowledge, exchange best practice and ensure coordinated planning of industry support initiatives.

ACKNOWLEGEMENTS

The detailed picture presented would not have been possible without data and input from many associations, government departments and passionate professionals. A big thank you to Loide Uahengo from the National Commission on Research, Science and Technology (NCRST) for the many contacts and for chasing outstanding data and to Dr John Samuel and Prof. Frank Kavishe for their help with higher education data and insights.

SOURCES OF INFORMATION

Data and information were gathered during interviews and telephone conversations, via email and from SADC reports, master plans and strategies as listed under *Plans and Strategies,* and from many standard international sets of data as listed in Chapter 5, *Research Approach*. Further information was gathered from news articles, such as those published by the *New Era*, *Namibian*, *Informante,* etc. and from Labour Force Surveys. Comprehensive documents focusing on specific issues in Namibia as listed below were invaluable sources of information.

EPA (Engineering Professions Association of Namibia). 2014. *The role of the engineering profession in Namibia*. Windhoek: EPA.

Kadhikwa, G. and Ndalikokule, N. 2007. *Assessing the potential of the manufacturing sector in Namibia*. Occasional Paper of the Bank of Namibia. Windhoek.

NTA (Namibia Training Authority). 2014. Construction skills plan. Khomasdal.

NTA. 2014. Energy, water and sanitation sector skills plan. Khomasdal.

NTA. 2014. Manufacturing and related industries sector skills plan. Khomasdal.

NTA. 2014. Mining and quarrying sector skills plan. Khomasdal.

NTA. 2014. Transport, warehousing and logistics sector skills plan. Khomasdal.

Sherborne, R. 2017. *Guide to the Namibian Economy 2017*. London: Institute for Public Policy Research.

Visser, T. 2017. *Who's Who Namibia*, Vol. 12. Windhoek: Virtual Marketing Publishers.

Visser, T. 2017. *Who's Who Engineering Namibia*. Windhoek: Virtual Marketing Publishers.

SEYCHELLES

THE SEYCHELLES, or officially the Republic of Seychelles, is an archipelago of 115 islands in the Indian Ocean. It has the smallest population of any sovereign state in Africa and the sixth smallest economy in Africa. Nearby island countries include Comoros, Madagascar and Mauritius.

Tourism accounts for a large portion of the Seychelles' GDP. In 2017, the islands welcomed a record high of 349 861 tourists, more than three times the population.

The country was classified by the World Bank as being a high-income country in 2015. Only 1.1% were classified as living below the international poverty line and 6.6% below the upper-middle income line of US$5.5 a day in 2013.

The capital is Victoria, which is the major industrial and urban centre. Victoria supports about 29% of the country's urban population and handles the export of vanilla, coconuts, coconut oil, and fish. Since the Seychelles is largely mountainous and development is limited to the coastal belt, continued urbanisation and expansion of manufacturing and even tourist facilities presents a problem in terms of land suitable for development. These development challenges are typical of those faced by Small Island Developing State (SIDS).

THE ECONOMY

Since independence, the country's economy has moved largely from agriculture to a market-based, diversified economy. The government has implemented sound macroeconomic policies and structural reforms, which have supported economic growth driven primarily by tourism, fisheries and information and communication technology (ICT).

The contribution to the GDP of engineering services is the lowest in the region, having dropped to just above 30% since 2009 as a result of increasing efforts to boost tourism. In 2016, tourism directly contributed 26% to the GDP, and made a total contribution of 58% since it involved many sectors.

The top exports are processed and non-fillet frozen fish. Further growth of the sector is expected through value-added activities which will be possible once the expansion of cold storage and processing facilities in Port Victoria are complete.

The Seychelles boasts of having the highest Africa Infrastructure Development Index (AIDI) in the SADC region and in 2016 took the lead with the highest Human Development Index in the region. Given the highly developed nature of the Seychelles, it is interesting to note that the ratio of engineering practitioners to population is also the highest in the region.

THE CHALLENGE OF BEING A SMALL ISLAND DEVELOPING STATE (SIDS)

Island states have particular challenges when considering long-term development. Many maritime countries classified as SIDSs face sustainable development challenges including susceptibility to natural disasters. Their growth and development is held back by their remoteness and limited resources, and related high communication, energy and transportation costs, irregular international transport volumes, disproportionately expensive public administration and infrastructure due to their small size, and little or no opportunity to create economies of scale.

They are usually densely populated and have limited space for development. The population density of the Seychelles was 208 people per square kilometre in 2017, which was 63rd on the global scale. Some areas are unusable due to difficult topography and

Table 1: Seychelles metrics

Population	
Total	96 000
Urban	56.7%
Rural	43.3%
Poverty, HIV, Unemployment	
Below the international poverty line	1.1%
HIV-positive	<1 %
Unemployment	4.4%
Human Development Index	0.772
Electricity	
Production kWh	350m
Consumption kWh	325.5m
Airports and Ports	
Airports	14
- Paved	7
- Unpaved	7
Ports	1
Kilometres of Services	
Roads	526
- Paved	514
- Unpaved	12
Africa Infrastructure Development Index	94.32
Access to Services	
Access to safe drinking water	95.7%
Access to improved sanitation	98.4%
Access to electricity	97%
Telephones	19 562
Mobile phones	167 282
Internet users	87%

access, further limiting development opportunities. As a result, the country has resorted to reclaiming land primarily on the eastern coast. The sustainability of land reclamation is a concern when considering long-term stability and the demands of a growing population. Land use planning and developing appropriate infrastructure presents problems in terms of high costs and the lack of professional capacity.

There is a need to balance the demand for land between commerce, agriculture and transportation. The number of vehicles has increased, despite high taxes, and traffic jams are commonplace. A light rail network for mass transportation has been suggested but is considered to be prohibitively expensive. There is also the need to preserve the traditional island-living persona, which defines its culture and heritage and on which the tourism industry relies.

PLANS AND STRATEGIES

To address the challenges outlined, there are several important plans and development policies in place, the most important of which are the:

- **Medium Term National Development Strategy (MTNDS) (2013–2017)** which focuses on developing tourism and fisheries with a view to strengthening economic growth and improving infrastructure, while ensuring environmental sustainability.
- **Seychelles Sustainable Development Strategy (SSDS) (2011–2020)** which sets out the roadmap for sustainable development through, among others, developing agriculture, water, sanitation, waste management, energy and transport solutions, and relevant capacity to overcome constraints.
- **Seychelles National Agricultural Investment Plan (SNAIP) (2015–2020)** which focuses on the need to expand local food production to address dietary needs.
- **Seychelles Water Development Plan (SWDP) (2008–2030)** focusing on meeting the ever-increasing water demands by managing water resources, increasing capacity, treatment facilities and using telemetry to improve demand management.
- **Seychelles Energy Policy (2010–2030)** which recommends sustainable development focusing on energy efficiency, renewable energy and reduced dependence on oil. Targets to increase renewable energy have been set at 5% by 2020, 15% by 2030 and 100% in the long term.
- **Seychelles Strategic and Land Use Plan 2040** which sets out the long-term spatial plan to grow the number of locations for development and to accommodate population growth.
- **Victoria Masterplan 2040** which sets out a strategy to guide the development of Victoria as the economic and cultural heart of the nation over the next 25 years.
- **National Human Resource Development Strategy (NHRDS) (2018–2022)** which is aimed at developing a more responsive approach to skills development.

ENGINEERING ACTIVITIES

Figure 1 shows the contribution of engineering-related economic activities to the country's GDP. The largest sector is transport and communications followed by manufacturing, the latter based largely on the processing of fish. Considering each sector in turn will give a picture of the activities, trends, challenges and opportunities for the engineering profession to contribute to the growth of the Seychelles.

AGRICULTURE

The economy of the Seychelles is based on fishing, tourism, the processing of coconuts, vanilla, coconut fibre, printing, furniture and beverages. Agricultural products include cinnamon, sweet potatoes, cassava,

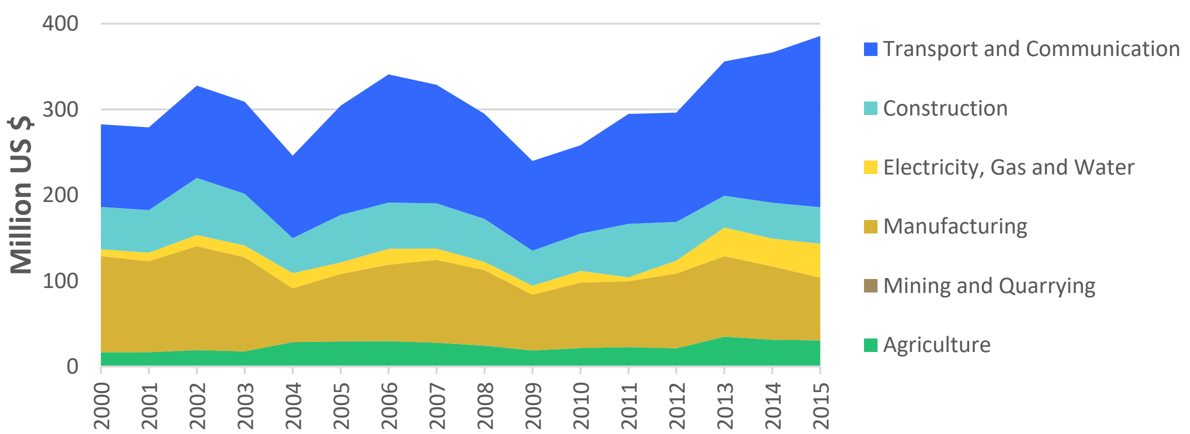


Figure 1: GPD per engineering related economic activity (34% of the GDP)

bananas, poultry and tuna. The traditional export crops, such as cinnamon, coconuts, patchouli and vanilla, have decreased considerably as vegetables and fruits grown for local consumption have increased.

Subsistence farming

Farming remains a small-scale activity, given the size of the country, with about 600 ha of land under agricultural production and about 200 ha under intensive agriculture. A total of 654 farmers, who farm on both private and state land, were registered with the Seychelles Agricultural Agency (SAA) in 2015. Some 48 farms are over 2 ha and 83 are less than 0.2 ha (or half an acre). Around 8 600 households are involved in some form of farming activity.

Commercial farming

The Agricultural Policy 2003–2013: Aiming for Higher Food Security through Sustainable Agricultural Production envisages optimising agricultural land use, improving arable and livestock production and improving services and institutional support. It recognises that developing reservoirs and irrigation systems are a particular challenge but are essential for year-round crops, as is the construction of shade houses. Several grant-funded projects have been implemented to expand the irrigated area and embrace new approaches and new technology.

When researching the support required for the Competitive Local Innovations for Small Scale Agriculture (CLISSA) Project, it was evident that there was a group of crops that could not be easily commercialised without agro-techniques, which require engineering skills.

Forestry

Little natural forest remains. Coconut plantations are the main source of timber, over and above imports. A reforestation programme projects the planting of 100 ha (250 ac) each year. Imports of forest products totalled US$1.4 million in 2004.

Fisheries

The waters around the Seychelles are home to over a 1 000 species of fish. While some species are protected, fishing is an important activity in terms of food supply, export earnings and employment. Tuna is the biggest export. Around 12% of the working population was employed in the sector in 2012, 70% of whom worked in the industrial fishery sector. The country's first solar energy-powered ice plant was installed in Bel Ombre in 2015, which now allows fishermen to increase catches and their income. As ships spend days at sea, major refrigeration units are required for freezing each catch.

MINING AND QUARRYING

The Seychelles' mineral production has traditionally consisted of granite, gravel, crushed rock and sand, used mainly in the construction sector.

Recently, drilling has revealed potentially large reserves of oil offshore. Oil exploration is underway, and geophysical and geochemical analyses indicate potential for commercial production, but the extent and impact that production may have on the environment must also be considered.

MANUFACTURING

Besides processed fish being the largest export, other export products include refined petroleum, non-fillet frozen fish, animal meal and pellets, recreational boats, fishing ships and paper labels. The manufacturing sector accounts for 26% of GDP.

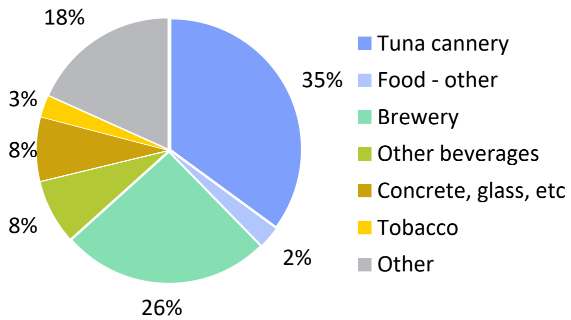


Figure 2: Manufacturing value add per subsector, 2018

(National Bureau of Statistics)

Food, beverages and tobacco products

Tuna processing and canning is a major contributor to the GDP as 95% of the canned tuna produced is exported to Europe under brands such as John West or Petit Navire. It takes less than five hours to process a fresh fish into a canned meal and the biggest tuna cannery produces 350 tons or 1.5 million cans every day. Opened in 1987 as the Seychelles Tuna Canning Factory and privatised in 1995 with a 60% purchase by US-based Heinz Inc, the tuna business has grown rapidly. The joint venture between Heinz and the government, now known as Indian Ocean Tuna (IOT), has recently built its own wastewater treatment plant to better manage waste and improve the quality of effluent. Processed fish is the largest export, with non-fillet frozen fish also being a significant export, indicating the importance of fishing and fisheries in the Seychelles.

A tea factory processes locally grown tea. Other factories process copra and vanilla pods and extract coconut oil. The largest beverage company, a brewery, also bottles soft drinks, international carbonated drinks and spirits under licence, and employs many engineering staff. There is also a cinnamon distiller. Other agro-processing includes the manufacture of cigarettes, animal feeds, processed meats and dairy products.

Textiles, clothing and leather

The Seychelles does not have a textile and clothing industry, therefore all of the country's demand is satisfied by imports.

Timber, pulp, paper and packaging

Local hardwoods are used in the manufacture of furniture and components in the construction sector, including doors, door frames, kitchen cabinets and roof trusses. Furniture and craft products, including carvings, are produced mainly by local carpenters and small-scale wood-working plants. Softwoods and wooden panels are imported, as are exotic papers and low-volume paper products. Locally produced paper products, such as toilet paper and packaging, are produced using imported paper and board. Charcoal is produced from waste due to logging and by hotels, using wood from their own forests.

Plastics, chemicals and other non-metallic mineral products

There is a plastics factory involved in injection moulding, another involved in plastic container and furniture production, a salt producer and a paint factory employing a few engineers. The Seychelles has amended its Environmental Law to prohibit polystyrene boxes, plastic bags and utensils, as well as requiring biodegradable forms of these products to conform to prescribed standards. These new regulations became effective on 1 July 2017 and will affect the current production of plastics.

As salt is a by-product of the desalination process, research into manufacturing activities requiring large volumes of salt should be considered. Cement is not produced locally, but is imported, stored near the commercial port and is bagged locally for distribution throughout the archipelago.

Pharmaceuticals

Apart from herbal medicines which are handmade locally, pharmaceuticals are imported. International Pharmaceuticals is the major importer and supplies the Seychelles Ministry of Health as well as some private pharmacies and clinics.

Metal industries, machinery and equipment

Most metal products, machinery and equipment are imported. However, there are companies involved in the manufacture of small boats, furniture and steel products and televisions are assembled locally.

ELECTRICITY, GAS AND WATER

Consumers in the Seychelles all receive their services from the Public Utility Company (PUC), which supplies both electricity and water, and manages the sanitation services for the entire country.

Electricity

Electrification has been extended to both the urban and rural population and by 2012, 97% of the entire population had access to electricity. The Seychelles has no exploitable natural resources and, therefore, historically has relied on imported petroleum products to meet most of its energy requirements.

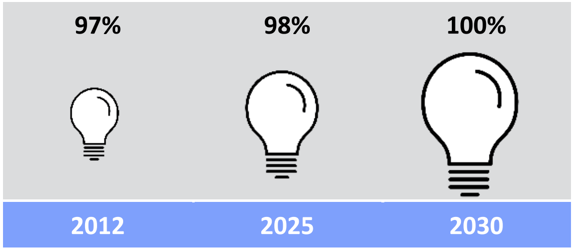


Figure 3: Target dates for access to electricity

However, in 2013 wind turbines were commissioned on the quay in Victoria, which have since been generating 8 million kW/h per year. The country is planning to increase its renewable energy consumption to 15% by 2030. A 5 MW solar plant is planned, along with additional generation capacity on several of the islands using small solar installations to service isolated sites.

Agreements with Independent Power Producers (IPPs) have been signed, to allow the private sector and foreign investors to augment the supply and sell back to the PUC. However, as the grid is small, the balance of diesel generated and renewables must be carefully managed to ensure that voltages do not increase too dramatically and cause damage to the network, and to consumers' appliances.

Engineers are generally trained in Mauritius, the UK, China, Malaysia and South Africa, and technicians in China and India. Given that the PUC electricity department plans and manages the development of the network, generates, transmits, distributes, maintains, meters and monitors the entire system, a significant team of engineering professionals is required. Currently an expert in renewable energy is training younger staff in renewable energy, but,

Figure 4: The wind farm in Port Victoria
(Courtesy: National Institute for Science, Technology and Innovation (NISTI))

ideally, additional local engineers in all subdisciplines are required to expand the technical team. In their absence, expatriates and consulting engineers are harnessed to fill the gaps.

For detailed studies and large projects, local consulting capacity is considered to be inadequate and such projects are let on open tender to the international community, whose scope of work is largely dictated by the funding made available.

The Blue Economy

The ocean is an important part of the world economy and offers opportunities for future economic growth, employment and innovation. The Blue Economy focuses on developing sustainable business models relating to the use of coastal and ocean resources and space. Not only does the Blue Economy create more opportunities for food security through fisheries and aquaculture, but also new technologies offer alternative energy options for harnessing offshore wind power, wave energy, tidal power and thermal energy conversion. Island nations in particular need to develop these alternative solutions to supplement their limited land-bound resources and reduce their reliance on oil imports. Specialist engineering and scientific training will be required to harness these emerging technologies.

Oil and gas

The Seychelles has no proven reserves of natural gas, and oil exploration is underway although there is high resistance to further development due to the negative impact this would have on the island ecology and tourism. At present all requirements are imported. Currently, state-owned Seychelles Petroleum Company is the only distributor of petroleum.

Water and sanitation

The population is well served with water and sanitation facilities, with 96% of both urban and rural communities receiving water and 98% having access to improved sanitation facilities in 2015. Universal access to both services is targeted for 2030, but may be achieved sooner according to various reports.

Despite a relatively high level of rainfall, the steep topography of the main island has presented a challenge for fresh water catchment, and many desalination plants have been installed to supplement the capacity from the only major dam, La Gogue.

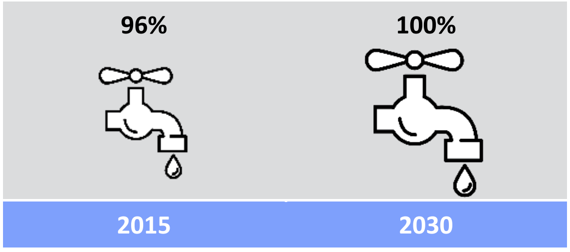


Figure 5: Target dates for access to safe drinking water

A limited number of households receive water-borne sanitation, with the balance utilising some form of dry sanitation solution. Due to the ground conditions and terrain, this presents a problem, as in the low-lying areas the water table is high, and pits must be lined to protect against water pollution, and in the mountainous areas, the rocky conditions do not allow the waste to percolate away.

A master plan for the upgrading to 100% water-borne sanitation has been prepared which will cost more than US$100 million over a 10-year period. To increase the water supply for this purpose, a new dam, the Grand Anse, will be constructed and the wall height of the existing dam, La Gogue Dam, will be raised to increase the capacity to 60%.

Although the Seychelles receives an average of 2 300 mm of rainfall per year, the stored capacity is very low due to there being few suitable dam sites. One million cubic metres of desalinated water is produced from four desalination plants every year and there are also plans to increase this number to meet future demand.

Desalination is an expensive process, as is treating of stored water; hence the new water-borne sanitation system will be unique in that it will not be fed with potable water. Two pipes will feed water to consumer properties, one to provide potable water for consumption, washing and cleaning purposes, and a second bringing recycled water into sanitation facilities. A waste pipe will take all the return flows to treatment facilities.

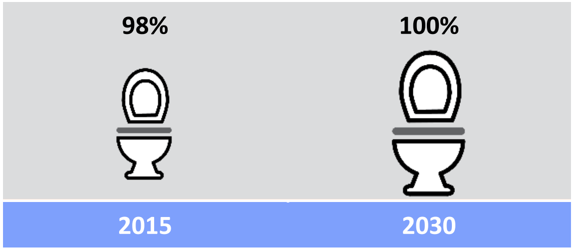


Figure 6: Target dates for access to improved sanitation

Once water-borne sanitation is in place, vastly increased wastewater treatment facilities will be required. A major facility is planned in Victoria and many plants are planned to service smaller centres. The range of infrastructure provided by the Water Unit requires expertise in many disciplines, including civil engineering for storage and reticulation, mechanical and chemical for desalination and treatment processes, and electrical and electronics for Supervisory Control And Data Acquisition (SCADA) systems and for instrumentation and control in general. The master plan also includes a substantial list of additional skills required to offer the extended scope of work, not least of which is maintaining the substantially extended networks. The Unit is also tasked with providing services to the other, smaller, inhabited islands.

To reduce dependence on desalination, groundwater is being considered as an alternative source. Over the years, water has accumulated in fractures in the granitic rocks that cover the island, effectively forming underground dams. Pumping and distributing this water is considered to be an option, particularly in the dry seasons, and exploration is underway to identify underground reserves.

TRANSPORT AND COMMUNICATIONS

The responsibility for transport and communications spans a number of ministries. The transport network falls under two ministries, namely the Ministry of Habitat, Infrastructure & Land Transport (MHILT), with Infrastructure taking responsibility for the urban roads, and Land Transport taking responsibility for the national roads; and the Ministry of Tourism, Civil Aviation, Ports & Marine (MTCAPM) taking care of ports and airports. There are no railway lines in the Seychelles. Communications falls under the Department of Information Communications Technology (DICT) in the Office of the President.

Roads

There are approximately 526 km of roads, of which 98% are surfaced. Traffic volumes have increased over the years, causing increasing congestion, particularly in Victoria. However, a number of key roads cannot be widened, since the road prism extends to the edge of pavements which give access to major buildings or abut retaining walls on steep slopes. Alternatives that have been considered are to construct a tunnel between Victoria and Beau Vallon or to construct an elevated highway or a light rail system. Road network expansion has not been financed by loans in the past and the government is reluctant to use loans for road construction since there is no direct source of revenue to ensure repayment. To adopt any of the above solutions, external financing will be required, and tolling will need to be introduced for the first two options. Use of public transport is being encouraged.

The increased traffic volumes, overloading and damage to pavements, and the fact that roads frequently need to be dug up for maintenance of PUC services, which were constructed below the road, means that the level and cost of maintenance is on the increase. A new policy has been introduced to ensure that new PUC services are laid beside the road, not under it. The shortage of staff, and lack of a comprehensive asset management system, present further challenges in terms of maintenance.

Rail

Due to the growing congestion, consideration has been given to developing a light rail system, but this has been shown to be prohibitively expensive.

Ports

Expansion and modernisation of Port Victoria is planned to increase the quay length from 270 m to 330 m. The expansion was expected to commence at the end of 2017.

Airports

There is only one international airport on Mahé, situated 11 km south-east of the Victoria central business district (CBD). Given increasing tourist volumes and plans to increase, among others, the export of fish products, the government has signed an agreement with State-owned Abu Dhabi Airports Company (ADAC) to expand the airport in phases, according to a detailed master plan. The development will incorporate green features and passive energy strategies, which include eco cells, green walls, sun shading and dye-solar panels.

Communications

Internet services commenced in 1996 and today there are five Internet service providers: Atlas, Intelvision, Kokonet, Airtel and Cable & Wireless Seychelles Ltd.

Since 2000 access has increased dramatically and internet connectivity is available in all the secondary schools on Mahé and Praslin. As of 2018, 87% of the population have access to internet services through a variety of technologies. Only 18% use fixed-line broadband, whereas 81% use mobile broadband. Although there is a much higher utilisation of mobile broadband, mobile data costs are still relatively high, with the cheapest offerings at US$7.66 per GB, compared with fixed-line data which costs US$2.45 per GB.

In terms of telecommunications, there are two active mobile network operators, Airtel and Cable & Wireless Seychelles Ltd. As of December 2017, there were 19 562 fixed-line telephones, and 167 282 had mobile subscriptions, which represents 175% of the population.

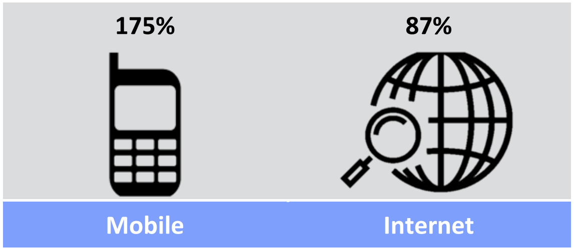


Figure 7: Percentage of population connected to services

Over time, the speed of services has increased as the backbone has been extended and in 2012, the 1 930 km Seychelles East Africa System (SEAS) submarine cable landed at Beau Vallon, Mahé, connecting the Seychelles with Tanzania. The SEAS cable was initially equipped at 20 Gbit/s with an ultimate design capacity of 320 Gbit/s. However, utilisation of the fibre optic SEAS cable is reaching 50%, with international bandwidth reaching 7.3 Gbit/s, indicating that local infrastructure upgrades need to take place to keep expanding the telecommunications network and make use of the highly expandable international fibre link. A further option would be to implement an additional fibre optic submarine cable, providing redundancy in order to prevent international network communication loss in the event of a submarine cable breakage.

Radio telecommunication is available to communicate between the islands in the archipelago, and satellite communication is available for international telecommunications in difficult-to-reach locations, but is far more expensive and less reliable than the fibre international link.

TOURISM

In the Seychelles, it is a requirement that all resorts provide their own services, including electricity, water and wastewater treatment. Thus, each resort or hotel chain becomes a mini-town requiring a full range of municipal engineering services, and associated professionals. The larger chains employ their own engineers, while the smaller resorts employ consulting engineers and the associated artisans for ongoing operations and maintenance.

CONSTRUCTION

Construction is important in any country due to its ability to create jobs and develop skills. There are 80 construction companies registered with the Seychelles Licensing Authority (SLA). The larger companies tend to be international. Given the substantial plans to boost tourism further and to enhance the infrastructure, many ambitious projects are planned, some of which are listed in Table 2.

Reclamation and coastal engineering

The small land area of the Seychelles and the granitic mountains in the centre result in fierce competition for scarce land between sectors of the economy. The main competitors are agriculture, housing and tourism.

Agricultural land continues to be compromised and, given the limited area for development, major reclamation projects have been undertaken over the past 20 years to increase the land area. Victoria's CBD, the site of the National Assembly, the Providence Industrial Estate, the power station, national stadium and several housing projects, schools and other industrial estates have all been developed on reclaimed land.

Given that the trend is likely to continue, it is important to ensure that there are sufficient engineers experienced in designing and maintaining reclaimed land. Reclamation and developments such as expanding the port, or constructing additional piers and jetties, disrupts the currents and can have a serious impact on adjacent coastlines. Coastal engineers are needed to consider the impact of development, and to design and manage protection measures.

Table 2: Major projects identified, or being planned or under construction

PROJECT		VALUE US$	START YEAR	END YEAR
Energy	Efficiency improvement of all power stations	$5.4m	2014	2018
	La Digue Distribution Network	$2.1m	2013	2018
	Mahé Distribution Network	$11.2m	2011	2018
	New Mahé Power Station (capacity – 40 MW)	$73.3m	2018	2020
	Praslin Distribution Network	$4.1m	2013	2018
Water	Grand Anse Dam	Planning and Costing		
	Upgrade the La Gogue Dam	$13.6m	2017	2019
	Waterfront bypass	Unknown	2018	2018
Other	Building second runway on reclaimed land	$150m		2019/2020
	Victoria Port expansion, including quay extension and dredging	$41m	2019	2021

Housing

The demand for housing is significant as the greater part of the population relies on the government to build and rent out houses in housing estates, the most prolific of these estates being on reclaimed Perseverance Island. The government builds 300 to 500 housing units per year, but current demand is for an annual 4 000 new homes. However, climate change poses a challenge as the country needs to prepare for more intense rains over shorter durations, which will impact the development of housing and roads along the coastal belt and on reclaimed land.

Abu Dhabi's Urban Planning Council (UPC) has been involved in a project to develop an economic strategy for the islands. Since May 2014, the UPC has been providing technical assistance and will set out the urban development framework for sustainable growth of the Seychelles up to 2040.

LOCAL GOVERNMENT

The Ministry of Home Affairs, Local Government, Youth, Sports, Culture, and Risk & Disaster Management is responsible for supporting communities in order to be directly involved in determining their needs to ensure their social and economic well-being. There are no separate municipalities supplying services to Victoria and the smaller centres. Local roads and amenities are constructed and maintained by the MHILT, while water and energy are supplied by the PUC.

EDUCATION, TRAINING AND PROFESSIONAL DEVELOPMENT

Education and training is a vital part of developing engineering capacity. All elements, from teaching appropriate subjects at schools to continuing professional development (CPD), need to be in place to educate and train engineering personnel and to ensure that they remain abreast of the latest technology, challenges and emerging solutions.

PRIMARY AND SECONDARY EDUCATION

Schooling is based on the British system, with two years of pre-school and six years (P1 to P6) of primary education. Secondary school consists of five years to 'O' Levels (S1 to S5), also known as the IGCSE (International General Certificate of Secondary Education), followed by an optional two years to A-levels (S6 and S7).

In 2016, 13% of the 1 300 learners in P6 scored an A, B or C in mathematics, only 120 of 360 in S5 scored similar results and 19 out of the 37 who wrote 'A' Level mathematics in 2015 scored an A, B or C. These are therefore the only learners available to enter engineering, financial, medical, actuarial and scientific degree studies in higher education. The number of engineers graduating and returning to the Seychelles each year has averaged four for many years, which was too low to supply the country's needs. This number has increased since 2016.

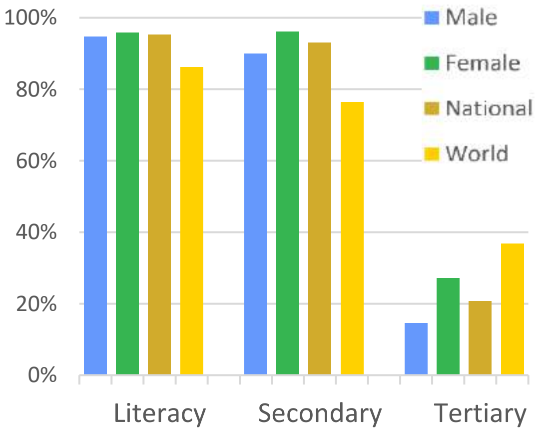


Figure 8: Literacy and enrolment statistics
(UNESCO from 2015 to 2016)

A shortage of teachers and decreasing interest in mathematics and scientific subjects (excluding IT) were cited as reasons for the poor performance. The takeover of the Teacher Training Institute by the university in 2011 is said to have disrupted teacher training for several years. Through an agreement with Botswana, teacher training has been offered in Botswana, and Batswana teachers have been used to fill the gap to some extent, but at times learners battle to understand the teachers.

Historically all subjects have been taught in Creole to P4. In a bid to improve mathematics results, from 2017, mathematics is being taught in English from P1. It is also evident that much extended career guidance and subject advice is required in secondary education to attract learners into engineering and ensure that they continue with mathematics to A-levels.

TERTIARY EDUCATION

Engineering diplomas and advanced diplomas are offered by the Seychelles Institute of Technology (SIT), as shown in Table 3. Formerly, engineering qualifications were offered through the Seychelles Polytechnic, but it was felt that since these qualifications were vocational, they should fall under the ministry that uses these skills. The School of Construction was merged with the School of Engineering to become the Technical Studies Programme Area within the Polytechnic in the late 1990s, and in 2005/2006 left the Polytechnic to become the SIT.

The programmes at the time were mostly City and Guilds (C&G) certificates and advanced certificates relating to trades, but more recently, diplomas have been offered full-time and advanced diplomas on a part-time basis for those with diplomas to develop as technicians. It should be noted that in terms of this study, the C&G diploma qualification is not equivalent to that of a technician, but rather the advanced diploma matches the technician requirements as described in the Dublin Accord.

No engineering degrees are offered in the Seychelles, which means that anyone wishing to complete an engineering degree must study outside the country. The Agency for National Human Resources Development (ANHRD), which falls under the Ministry of Education and Human Resource Development, is responsible for coordinating national human resource planning, utilisation and development in both the public and private sectors. As one of its mandates, it manages the Government of Seychelles Scholarship Scheme and tertiary training fund.

Government departments and the private sector can make recommendations or lodge requests for scholarships to be awarded in their fields, to develop the future capacity. Funds are only awarded in areas of national priority. Students receiving overseas scholarships are required to return to the Seychelles within two months of completing their studies.

The graduation statistics for engineers and technicians in 2015 are shown in Table 3. The number of engineers returning and their disciplines are shown in Table 4 and the increase over the 11 years is plotted in Figure 9. The split by gender, category and discipline of all graduates is shown in Figure 10. It should be noted that environmental and petroleum engineering are not shown in Figure 10 as students have only recently embarked on these qualifications.

Of concern at present is the fact that full scholarships are only available to those studying medicine, teaching and tourism/hospitality management. Given the shortage of local engineering skills and the role that they can play in growth, consideration should be given to adding engineering to the high-priority list. Degreed mechanical, telecommunications, civil and electrical engineers were listed in the Human Research Demand requirements for the country from 2012 to 2016.

Accreditation

Seychellois graduates returning and expatriates arriving are required to submit details of their qualifications to the SQA for assessment of their equivalence to or recognition on the National Qualifications Framework. This has become important to establish employment levels and salaries, with an increasingly mobile workforce whose qualifications are said to be equivalent, but who come from countries with different awarding systems.

Student mobility

In 2015, there were a total of 49 Seychellois studying at South African universities, of whom eight were studying by correspondence through the University of South Africa. There were no engineering graduates from the Seychelles in 2015, and only four engineers have graduated in South Africa since 2005.

The government has committed itself to having at least one university graduate per household, but this will need to be complemented by a retention strategy to ensure that graduates remain within their field of expertise and contribute meaningfully to the development of the country. Retention of professionals is difficult in view of the limited remuneration, limited availability of quality goods and services, and slow country development, among others.

Table 3: Engineering graduations in 2015

INSTITUTION	QUALIFICATION	Civil/ Construction	Electrical	Mechanical	Software	Telecommun-ications
Returning graduates	Degree	4	2 (2016)	1	1 (2016)	
Seychelles Institute of Technology (SIT)	Advanced Diploma	9				11 (2017)
	Diploma	7		1		7 (2017)
TOTAL						
Engineer (8)		4	2	1	1	
Technician (20)		9				11

Table 4: Graduates engineers on bursaries returning to the Seychelles since 2008

COURSE / YEAR	2008		2009		2010		2011		2012		2013		2014		2015		2016		2017		2018	
	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F
Mechanical Engineering											2				1				2		2	
Civil, Construction, Structural Engineering	1		3		1		3		1		2	1	3		4		5	2	4	1	4	4
Software Engineering																	1		1		1	
Environmental Engineering																				1	1	
Petroleum Engineering																					2	
Electronic Science, Technology, Biomedical, Electrical Engineering	2		2						2		1		2				2				2	
TOTAL PER YEAR (66)	**3**		**5**		**1**		**3**		**3**		**6**		**5**		**5**		**10**		**9**		**16**	

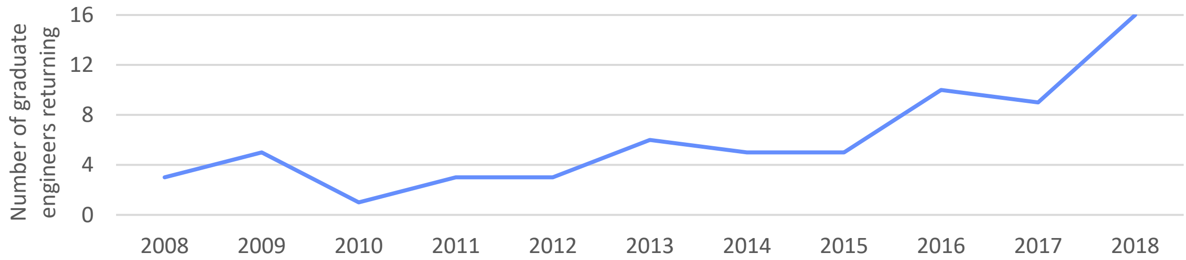


Figure 9: Number of graduate engineers returning per year

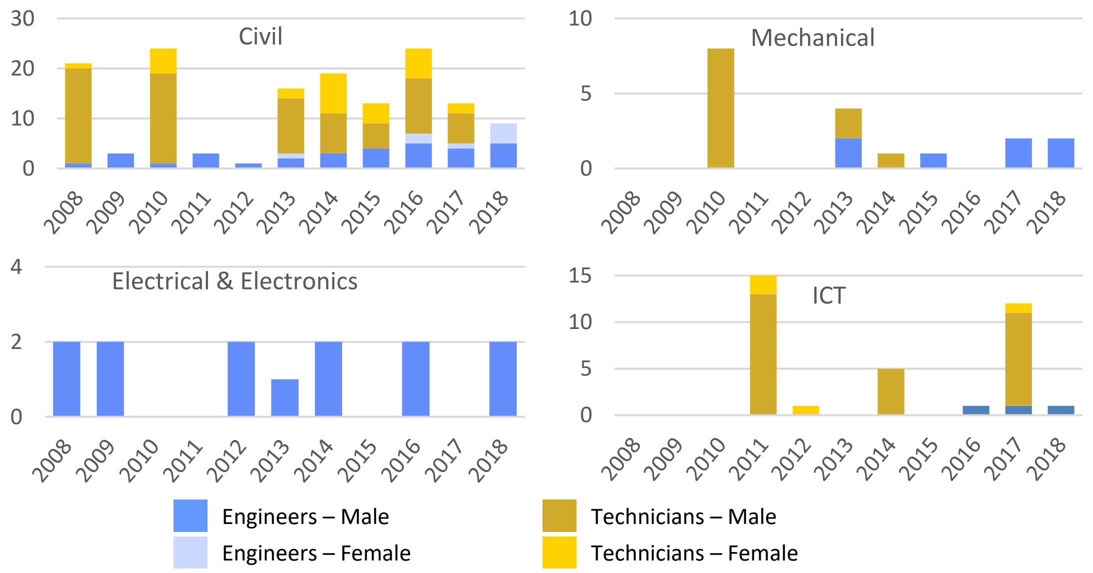


Figure 10: Engineering graduates by discipline, category and gender

SEYCHELLES

The majority of students completing degrees outside the country study in the UK. Several have studied in India, Mauritius, Egypt and China and a few have studied in Australia. There are a few Indian students studying at SIT, but these are generally students whose parents are working in the Seychelles.

GRADUATE TRAINING

Once the tertiary education phase is complete, it is necessary for graduates to receive structured training in the workplace, under professional supervision and mentorship, to develop to the level of competence required for professional registration, and to be able to take on work independently. Many public-sector departments and parastatals offer structured training in the first year or two after graduation. Unlike in most other countries in the region, many of these departments carry out in-house design, thus giving graduates the opportunities to apply their theoretical knowledge and hone their problem-solving skills.

In terms of international registration standards, the duration of graduate training in some instances is possibly too short to develop the level of competence required to take responsibility for complex engineering work. Consideration should be given to extending the graduate-in-training phase, and conditions need to be set in the employment agreements with experienced staff to coach and mentor junior staff, as part of the key performance indicators (KPIs).

PROFESSIONAL REGISTRATION

The Departments of Infrastructure and Planning are busy preparing a bill for submission to parliament to establish an Engineering Act and compulsory registration of engineering practitioners. This is required, given the global village and mobility of skills, to ensure that those who claim to be professional engineers can operate at the level of complexity and responsibility expected of engineers. It is suggested that the Seychelles work within the International Engineering Alliance framework to ensure equivalence of local registration with international best practice. Once in place, more formal efforts at graduate training, as discussed above, will need to be made to ensure that the potential of all returning graduates is fully developed.

VOLUNTARY ASSOCIATIONS AND CONTINUING PROFESSIONAL DEVELOPMENT (CPD)

Once professional registration is in place, it will be necessary to ensure that registered professionals can participate in CPD activities to keep up to date with the latest technologies, trends, legislation, etc. Typically, voluntary associations (VAs), acting as interest groups, deliver training for their members. In about 2005, the Association for the Construction and Engineering Professionals of Seychelles (ACEPS) was formed, with a view to being the voice of the built environment and growing its members professionally. Although ACEPS was launched with great enthusiasm, interest waned rapidly, and the organisation ceased operation in 2008.

In 2009, the Contractors and Maintenance Association was launched to represent the needs of its members. Sadly, it seems that this organisation is also no longer in existence. There is a need to put some sort of VA in place to represent the views and interests of the industry and offer CPD. Based on recognition of the need for Life Long Learning, as articulated in the NHRDS, ANHRD should consider funding the setup of a VA and CPD system, as currently they are funding attendance at short courses outside the country, which is expensive given the cost of overseas travel; thus funds are limited to a small number per topic.

WOMEN IN ENGINEERING

Given the small number of engineering practitioners in the country, the very low percentage of female engineers and the lack of an engineering VA, there do not appear to be any Women in Engineering initiatives.

THE WORKFORCE

According to the 2016 quarterly labour force surveys issued by the National Bureau of Statistics, there are slightly more than 300 engineers and 200 technicians in the Seychelles. Although this is said to be only an approximation due to the small sample size of the household survey, this number agrees with the sample responding to the current survey, which included 98 engineers and 60 technicians from a

Table 5: Distribution of disciplines versus category in 2018

DISCIPLINE	ENGINEER	TECHNICIAN
Mechanical	17.4%	20.0%
Electrical	39.1%	29.2%
Civil	38.0%	13.9%
Aeronautical	0.0%	20.0%
Chemical	1.1%	0.0%
Marine	2.2%	16.9%
Mechatronics	2.2%	0.0%
TOTAL	**100%**	**100%**

selection of ministries, manufacturing plants and the construction industry. The distribution of disciplines per category is shown in Table 5.

THE PRIVATE SECTOR

The main employers in the private sector are consulting, contracting and manufacturing companies, suppliers and quarries. Lower numbers are employed in small entrepreneurial companies, NGOs, training organisations and other companies where engineering input is required.

Given the shortage of professional and technical skills, many expatriates are appointed, but to ensure that they are not appointed to the exclusion of Seychellois, the Guideline for Recruitment of Non-Seychellois Workers dictates the ratio of expatriates to Seychellois for many industries, including tourism, manufacturing and construction. Each company must be classified, according to size and type of business, by the SLA, the authority that licenses all businesses. Once the class of company has been established, the ratio of locals to expatriates can be determined according to the formula per class of company.

Consulting

There are some 20 consulting engineering companies in the Seychelles. Some are small, mainly one-man Seychellois specialist designer companies, while others are multi-disciplinary. The larger companies are mostly branch offices of multi-nationals.

In terms of project awards, the small companies generally do not have the capacity to handle large contracts, hence they are awarded to international companies, many of which do not have offices in the Seychelles but perform their designs offshore. There is a desire to see local companies grow or form joint ventures to handle larger projects.

Years ago, the Seychelles Association of Consultants was formed to encourage the development of local consulting firms but, given the size of the sector, it did not receive the desired support.

Contracting

There are some 80 civil engineering and building contactors classified and registered with the SLA which employed 2 148 workers in 2012. The government tries to award as many projects to local contractors as possible. However, in the case of large construction works such as dam construction where specialist expertise and significant machinery and equipment is required international contractors may be selected. Depending on their size, they are required to employ a certain number of Seychellois. The smaller local contractors generally do not employ engineers, but rather experienced artisans.

Manufacturing

There are some 330 manufacturers classified and registered with the SLA, though many are small companies relying on labour to make their products. It is estimated that there are some 35 manufacturers who require one or more engineers and/or engineering technicians. In 2012, 5 020 workers were employed in manufacturing, mining and quarrying, and other industrial activities.

Mining

The mining sector employs only a small number of the 5 020 workers quoted above, who are involved in quarrying granite, gravel, crushed rock and sand used mainly in the construction sector.

THE PUBLIC SECTOR

Many engineering practitioners are employed in the public sector. Ministries employing the largest numbers are shown in Table 6.

The Ministry of Environment, Energy and Climate Change employs around 60 engineering practitioners, mainly in the PUC. The Department of Home Affairs, the Ministry of Habitat, Infrastructure and Land Transport and the Presidential Offices, each employ about 35 engineering practitioners, the former mainly in transport-related structures, and the latter in Defence and the range of communication services.

The other ministries shown employ between 4 and 10, suggesting that there are some 160 to 170 engineering practitioners employed in the government.

The 'brain drain' is a hot topic in the Seychelles. This is especially pertinent in the government service sector where there is an acute shortage of technical staff, and retention of specialists poses a challenge.

Following the 2008 macro-economic reform, the number of employees in the public sector was significantly reduced. Numbers, however, continued to fall and in 2010, limited financial resources were cited as a contributor to capacity constraints. The inability to pay competitive salaries and other conditions of service led to high staff turnover and losing trained staff to other employers within or outside the countries of the region.

SKILLS IN GENERAL

Despite the measures to support professional, technical and vocational training, the loss of

Table 6: Ministries employing engineering practitioners

MINISTRY/STRUCTURE
Ministry of Environment, Energy and Climate Change • Public Utilities Corporation (PUC) • Seychelles Waste Management Authority • Seychelles Energy Commission • Seychelles Meteorological Authority
Ministry of Finance, Trade, Investment and Economic Planning • Department Economic Planning • Seychelles Licensing Authority • Seychelles Petroleum Company Limited (SEYPEC) • Seychelles Postal Services Ltd (SPS) • Seychelles Investment Board • Housing Finance Company (HFC) • Department of Finance and Trade • Seychelles Bureau of Standards
Ministry of Fisheries and Agriculture • Seychelles Agricultural Agency (SAA) • Seychelles Fishing Authority
Ministry of Habitat, Infrastructure and Land Transport (MHILT) • Seychelles Land Transport Agency • Seychelles Public Transport Corporation • Seychelles Fire and Rescue Services Agency • Seychelles Planning Authority • Property Management Company
Ministry of Tourism, Civil Aviation, Ports and Marine • Seychelles Ports Authority • Air Seychelles • Seychelles Civil Aviation Authority
Ministry of Health (MOH) • Public Health Authority • Health Care Agency
Ministry of Home Affairs, Local Government, Youth, Sports, Culture, and Risk & Disaster Management • Department of Local Government • Department of Home Affairs • Department of Risk & Disaster
Office of the President • Seychelles Peoples' Defence Force
Office of the Vice-President • Department of Information Communications Technology (DICT) • Seychelles Broadcasting Corporation • Enterprise Seychelles Agency • Petro Seychelles • National Institute for Science, Technology and Innovation (NISTI)

professionals in all sectors and the shortage of skilled tradesmen continues to leave serious gaps. This has also been recognised in the NHRDS.

Each sector complained of the difficulty in finding local engineering staff. Public sector officials in particular cited poor salaries as a reason not to return to the country to work in their sector, and those in the private sector complained that once students had graduated overseas, the opportunities for them were so vast that they did not return. As a result, posts were filled by expatriates.

Although many expatriates are suitably qualified and experienced, their command of locally used languages are often poor. As a result, they cannot always contribute meaningfully to think tanks and strategic planning sessions, nor can they be harnessed to assist with skills transfer, mentoring and coaching of the younger group of local engineers and technicians.

All organisations expressed the need for more engineering staff, but required experienced staff. There is definitely a need to fund more Seychellois to study engineering, but linked to contracts to return and to follow graduate programmes to develop the competence required to ultimately take responsibility for their work. In terms of salaries, a national discussion has been taking place to incentivise experienced local engineering staff to return and to encourage young professionals to remain in the country. Once the registration process, discussed above, is in place, salary adjustments linked to the attainment of professional registration and level of responsibility should be considered.

MIGRATION TRENDS

Analysis of the United Nations Population Division statistics for 2015 shows a net loss of professionals from the Seychelles. Of those entering the country, 40% were from India and 20% from Kenya. Those leaving mostly went to the United Kingdom and Northern Ireland, Australia, Italy and South Africa.

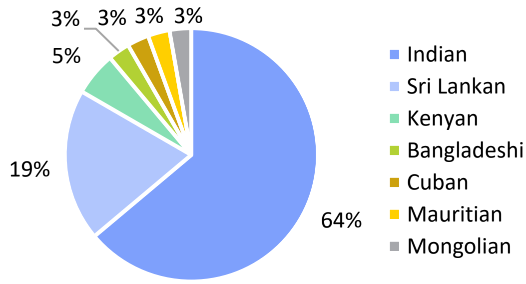


Figure 11: Distribution of foreign nationals working in the Seychelles in the survey sample

The survey carried out in all engineering and related companies during 2017 showed that 80% of all engineering practitioners were Seychellois. India and Sri Lanka made up 64% and 19% of the foreign nationals respectively. The balance have come from a range of countries, as shown in Figure 11.

ENGINEERING NUMBERS AND NEEDS

When all the data are combined as shown in Table 7, there is close agreement with the numbers gathered in the labour force surveys. Considering all the developments planned, the vacancies and the challenges with maintenance, there is clearly a need for more qualified and well-experienced engineers, and engineering technicians.

Figure 12 shows the current workforce, the losses that will occur over the 18-year period to 2035 due to retirement, mobility and mortality, and the growth in engineering capacity if engineering graduations increase at 2% per year over the period. Graduations are based on the assumption of 16 graduate engineers returning to the Seychelles each year and 16 technicians joining the workforce from the SIT.

The blue dotted line shows the growth in skills that would be required at the 2017 GDP growth rate of 5.3%, and the green dotted line shows the growth based on the 2018–2023 GDP projection of 3.6%. A 70% employment elasticity factor has been used to extrapolate the employment demand.[*1]

The rate at which bursaries have been increased and graduate numbers have grown appears to be close to the number required to keep pace with growth, based on the current workforce. However, should the government commit to filling vacancies, increasing the number of technical staff in operations and maintenance teams, investing substantially in new infrastructure development and expanding the manufacturing sector, many more graduate engineers and technicians will be required, along with comprehensive graduate training. This is in line with the NHRDS view that more TVET graduates are required. The number of engineers and technicians graduating per year would need to increase by a total of 18 to 20 to match the Agenda 2063 projection.

Table 7: Estimated numbers of engineering practitioners in the engineering workforce

SECTOR	ESTIMATED NUMBER
Academia and research	20
Agriculture	20
Consulting	50
Contracting	90
Government incl. municipal	170
ICT, systems and telecommunications	30
Manufacturers and suppliers	90
Mining and quarrying	10
Miscellaneous and NGOs	20
Tourism	10
TOTAL	**510**

The current ANHRD projections are therefore of concern as they do not indicate the need for more engineering bursaries. These should continue annually and be increased every few years to keep up with economic growth and the associated engineering skills demand.

At present complaints about the shortage of engineers mask the fact that the shortage in fact relates to a shortage of experienced and specialist skills. Specialist and management training and leadership development will also be important once graduates have developed the level required for professional registration. Life-long learning and development is critical as outlined in the NHRDS.

The NHRDS also laments the limited skills research and the lack of responsiveness to labour market needs. The scope of the current project has addressed these issues to a large extent for the engineering profession. The Seychelles is in the privileged position of having a small, well-educated population and should take advantage of technology to build a comprehensive database of all scientific and technical staff to assist with future skills planning.

The National Institute for Science, Technology and Innovation (NISTI) has developed a platform to collect and share information related to education, research development and innovation, but hopes to cover more sectors. The main aim of the platform is to make data easily accessible. This will be beneficial for decision-makers, the general public, academia, students, lecturers and schools. An application programming interface (API) allows those with data to interface to the system, thus ensuring that data on the portal is up to date at all times.

With data having been gathered for one-third of engineering practitioners and many more artisans as part of the Numbers and Needs research, it has been suggested that this information should be mounted on the portal and that NISTI should continue to

[*1] Employment elasticity is a measure of the percentage change in employment associated with a 1% change in economic growth. If the growth is likely to be in agriculture, the percentage could be lower, as growth in that sector is generally to do with productivity gains and not employment, whereas if the growth is likely to be in high-tech manufacturing, the elasticity factor may be more than 100%. These considerations will need to be factored into Human Resource Demand Planning.

SEYCHELLES

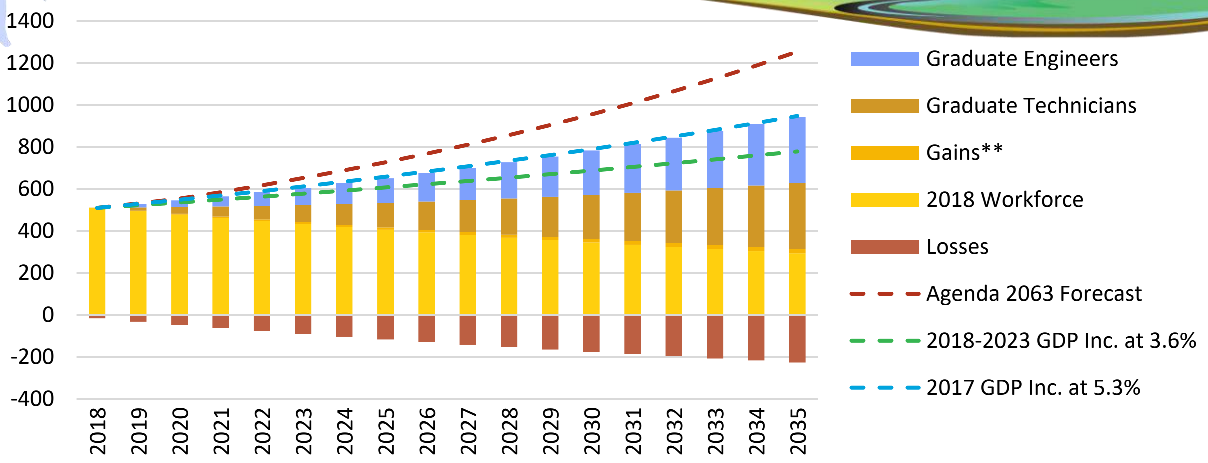


Figure 12: Flow of engineering skills based on a 2% increase in graduation rate per year

***Excludes international engineering practitioners in the country on short-term contracts*

engage with the remaining employers of engineering practitioners to build an online, real-time dataset to allow for better planning. This will allow more focused decision-making on the types and quantum of engineering skills to be developed.

When the number required at present is reviewed, consideration should be given to the following:

- **Agricultural engineering:** There do not appear to be any agricultural engineering graduates practising in the country. Given the desire to expand irrigation systems and manage water resources more effectively, consideration needs to be given to bursaries for students to complete agricultural or irrigation engineering qualifications from time to time.
- **Chemical engineering:** There is no evidence of chemical engineering bursaries being awarded in the past 15 years. Given the paucity of chemical engineers, which are needed in the food and beverage sectors and desalination, chemical engineering bursaries should be made available from time to time.
- **Civil engineering:** Civil engineering practitioners represent the second largest group of engineering practitioners. Funding should be made available for civil engineering degrees on a regular basis to ensure a steady flow. Furthermore, funding of specialist qualifications in land reclamation, coastal engineering and desalination technologies should be considered. The training of construction technicians should also continue.
- **Electrical engineering:** Electrical engineering practitioners represent the largest group of engineering practitioners. Funding should be made available for electrical engineering degrees on a regular basis to ensure a steady flow. Electrical engineering practitioners are required for generation; transmission and distribution systems; the use of renewable energy; in manufacturing processes and in the design of IT systems, electronic equipment and automation, among others. The training of electrical technicians should continue for overseeing many of these processes.
- **Industrial engineering:** No industrial engineers were identified in the research. Industrial engineers play a significant role in terms of improved production and streamlining systems. Consideration should be given to funding the training of industrial engineers from time to time.
- **Mechanical and marine engineering:** There are major roles for mechanical and marine engineering practitioners to play in production processes, fleet management, boat manufacture and power generation, among others. Funding should be made available for mechanical and marine engineering degrees on a regular basis to ensure a steady flow. The training of mechanical and automotive technicians should continue for overseeing many of these processes.

KEY RECOMMENDATIONS

To develop a sound pool of engineering professionals, able to contribute to the well-being of the Seychelles, the following should be considered:

Schooling

- **Mathematics and science:** Strengthen the teaching of mathematics and science to increase the number completing secondary education with acceptable results.

- **Career guidance:** Expand career guidance to attract both genders into the engineering profession.
- **Bursaries:** Provide bursaries to attract those who excel in mathematics and science to study engineering.
- **Studies outside the country:** Offer bursaries for students to complete engineering degrees outside the country based on demand and ensure that international institutions selected offer qualifications that will be recognised by the new registering body.

Tertiary education

- **Technician qualifications:** Enhance the engineering advanced diplomas to meet the requirements of the Dublin Accord.
- **Industry liaison:** Liaise with industry on a regular basis to ensure that curricula, methods, software and equipment used are relevant and up to date.
- **Curricula:** Provide funding to research, modernise or develop curricula and material where required.
- **Resources:** Raise funding for computers, engineering software, access to online reference material, and laboratory and other equipment, and ensure adequate support to offer technology-relevant training.

Graduate training

- **Develop programmes:** Develop graduate training programmes to ensure graduates achieve the level of competence required by industry and for professional registration.
- **Private sector incentives:** Offer incentives for private sector companies to develop graduates.
- **Public sector support:** Ensure that public sector structures take on and train graduates and that they are absorbed and developed through the ranks.
- **Institutional support:** Institutionalise graduate training in all organisations by setting KPIs for experienced staff to act as supervisors and mentors.
- **Project support:** Make graduate training a requirement of all public sector projects and ensure that the progress of graduates is monitored, and penalties are imposed for non-compliance.

Registration of engineering professionals

- **Registration:** Finalise and adopt the new Engineering Professions Bill and fund the development of a new institution until it is able to operate as a fully-fledged learned society and registering body.

Continuing development

- **CPD:** Support the participation of engineering practitioners in CPD activities.
- **Post-graduate studies:** Provide post-graduate bursaries to develop specialists.
- **Develop managers and leaders:** Encourage industry to continue investing in graduates after professional registration to grow management and leadership capabilities.

Registration of service providers

- **Licencing:** Consider expanding the licencing criteria for contractors to:
  - Ensure that there are requirements for consultants and contractors to train graduates, artisans and other construction-related skills.
  - Ensure that international consultants provide all calculations, drawings, operating manuals and other reference material in English or French, as agreed with the client body.
  - Ensure that local consultants, along with the client, check that design proposals address local needs and customs and that design calculations comply with national codes and standards.

The public sector

- **Economic infrastructure:** Invest in the development of economic infrastructure such as electricity, roads, rail, ports and airports, and address the supply of water services.
- **Maintenance:** Invest in maintenance to preserve new infrastructure and prevent further deterioration of existing infrastructure.
- **Tariffs and payment:** Review and increase tariffs where appropriate, enhance domestic revenue collection and demand management to fund development.
- **Technical capacity:** Reprioritise budgets to fill vacant posts and build technical capacity, ensure that salaries are competitive and develop succession plans to make the public sector an employer of choice.
- **Technical decision-makers:** Ensure that engineers are employed in senior decision-making posts.

Industry-wide collaboration

- **Advisory team:** Set up an engineering advisory team, recognised by government, to advise on and endorse infrastructure development proposals, tertiary curricula and graduate training programmes.
- **National data:** Support NISTI to develop a central database of all STEM occupations for purposes of manpower planning.

ACKNOWLEDGEMENTS

The detailed picture presented would not have been possible without the support of Dr Xavier Estico of NISTI, who made research capacity available. A big thank you to Tessa Bell assisted by Kevin Fabien, both from NISTI, who collected screeds of data, and to Kevin Bistoquet for numerous data extracts from the National Bureau of Statistics. Thanks too for the extensive input and ideas provided by passionate engineers in various engineering ministry staff and consulting engineers.

SOURCES OF INFORMATION

Data and information were gathered when attending a NISTI conference in 2017, during meetings, interviews and telephone conversations, and via email and Skype. SADC reports, master plans and strategies as listed under *Plans and Strategies*, and many standard international sets of data as listed in Chapter 5, *Research Approach,* were also consulted. Further information was gathered from news articles, such as those published by the Seychelles News Agency, the *Seychelles Weekly,* etc. and from Labour Force Surveys. Comprehensive documents focusing on specific issues in the Seychelles as listed below were additional sources of information.

AfDB (African Development Bank). 2015. *Seychelles Infrastructure Action Plan*. Abidjan, Côte d'Ivoire: AfDB.

ANHRD (Agency for National Human Resource Development). 2014. *Human resource demands for the country from 2012 to 2016. Information booklet.* Victoria Town: ANHRD.

Imanow, T. 2011. *SADC Rules of origin in textiles and apparel: Review and policy options*. Technical Report, Washington, DC: USAID.

Morel, G. 2014. Competitive Local Innovations for Small Scale Agriculture (CLISSA) Project: A market study and gap analysis report. Rome: International Fund for Agricultural Development (IFAD)

Republic of Seychelles National Report. 2013.

Vielle, M. 2001. Forestry outlook studies in Africa. Seychelles. Rome: Forestry Outlook Studies in Africa (FOSA).

UNCSD (United Nations Conference on Sustainable Development). 2012. *National Report. Republic of Seychelles*. Paper presented at the Earth Summit, Rio de Janeiro, Brazil.

WTTC (World Travel & Tourism Council). 2017. *Travel & Tourism Economic Impact 2017. Seychelles*. London.

SOUTH AFRICA

SOUTH AFRICA occupies the southern tip of Africa, its long coastline stretching almost 2 800 km along the south Atlantic coast and around the tip of Africa into the Indian Ocean. It is bordered in the north by Namibia, Botswana and Zimbabwe, on the east and north-east by Mozambique and Eswatini, and surrounds the Kingdom of Lesotho.

The country has nine provinces, which vary considerably in size. The smallest is Gauteng, a tiny, crowded, highly urbanised region, and the largest is the Northern Cape, a vast and arid region, which takes up almost a third of South Africa's total land area.

In 2017, South Africa was the largest producer in the world of platinum, the fourth-largest of diamonds, the sixth-largest of iron ore and the seventh-largest of gold. The country is also known to have 80% of the world's manganese and 70% of the world's chrome reserves.

Some 18.9% live below the international poverty line and unemployment is a high 25.3%. South Africa has a dual economy, with one of the highest inequality rates in the world.

South Africa has the fourth-highest HIV/AIDS prevalence rate in the world at an estimated 12.7%, placing a substantial burden on the economy.

Unlike the other SADC countries, South Africa has many major metropolitan areas. In the smallest province, Gauteng, which was at the heart of the early mining boom, there are three major cities, namely Johannesburg, Ekurhuleni and Pretoria, the latter being the administrative capital of country. The province is home to almost 11 million people. Other major centres, mainly port cities, have populations ranging from approximately one million (Port Elizabeth, East London and Mangaung) to over three million (Durban and Cape Town). Cape Town is the legislative capital.

Urbanisation is on the increase, but limited job opportunities for unskilled or semi-skilled labour have resulted in many informal settlements developing.

THE ECONOMY

South Africa is one of the most industrialised economies in Africa and it is the second-largest economy after Nigeria. It is classified as an upper-middle-income economy by the World Bank.

Inefficient government bureaucracy, red tape, restrictive labour regulations, a shortage of skilled workers, political instability, corruption, crime and a poor work ethic are cited as the top challenges to doing business in South Africa.

The non-engineering services sectors, including the wholesale and retail trade, education and financial services sectors, have contributed 60% or more of the GDP for many years, with manufacturing, mining and construction contributing only 13.5%, 7.9% and 4% respectively in 2016. The country has struggled with prolonged de-industrialisation, which is a

Table 1: South African metrics

Population	
Total	56 521 000
Urban	62.9%
Rural	37.1%
Poverty, HIV, Unemployment	
Below the international poverty line	18.9%
HIV-positive	12.7%
Unemployment	25.3%
Human Development Index	0.666
Electricity	
Production kWh	234.5bn
Consumption kWh	207.1bn
Airports and Ports	
Airports	566
- Paved	144
- Unpaved	422
Ports	8
Kilometres of Services	
Roads	750 000
- Paved	158 124
- Unpaved	591 876
Rail	20 986
Pipelines	3 839
- Oil	992
- Gas	1293
- Refined products	1460
- Other	94
Africa Infrastructure Development Index	78.53
Access to Services	
Access to safe drinking water	91%
- Urban	99%
- Rural	76%
Access to improved sanitation	80%
- Urban	92%
- Rural	60%
Access to electricity	85%
- Urban	90%
- Rural	77%
Telephones	4 522 850
Mobile phones	82 412 880
Internet users	54%

challenge in terms of job creation. To date, no country has transitioned from middle- to high-income status without the presence of a vibrant manufacturing sector. The Industrial Policy Action Plan 2017–2020 has targeted several sectors, including agro-processing, clothing, textiles, leather and footwear for re-industrialisation.

PLANS AND STRATEGIES

There are several important plans and development policies in place, the most important of which are:

- **National Development Plan (NDP)** which aims to eliminate poverty and reduce inequality by 2030. The core focus of the plan is on building capabilities, enhancing the capacity of the state, and promoting leadership and partnerships throughout society, to address education and skills development, decent accommodation, safe communities, transport and job opportunities.
- **Industrial Policy Action Plan (IPAP)** which aims to support radical economic transformation through efforts to diversify the economy and provide strong support for value added manufacturing. Transversal areas considered are public procurement, industrial financing incentive schemes, innovation and technology and Special Economic Zones (SEZs).
- **National Water and Sanitation Master Plan (NWSMP)** which is intended to guide the water sector with investment planning for the development of water resources and the delivery of water and sanitation services until 2030, and beyond.
- **Integrated Energy Plan** which is the overarching energy plan combining the constraints and capabilities of alternative energy carriers to meet the country's energy needs through the building of a fleet of new energy generation plants for the period 2010 to 2030.
- **Integrated Resource Plan (IRP) 2010–2030** which is the coordinated schedule for generation expansion, including renewable, nuclear, coal and other generation sources and, demand-side intervention programmes.
- **National Transport Master Plan 2050 (NATMAP 2050)** which proposes seamless multi-modal trade corridors and safe, affordable and accessible modal options for passengers.
- **Human Settlements Vision 2030: On the Road to 2050** which focuses on the total eradication of backlogs of more than 2.1 million housing units.
- **Human Resource Development Strategy 2030** which aims at strengthening basic education with special attention being given to mathematics, science, technology and engineering, expanding access to quality post-schooling education and training, producing appropriately skilled people for the economy, developing of a capable state, and enhancing research and innovation.

ENGINEERING ACTIVITIES

Figure 1 shows the contribution of engineering-related economic activities to the country's GDP. The largest sector is manufacturing, followed by transport and communications, and then mining. Considering each in turn will give a picture of the activities, trends, challenges and opportunities for the engineering profession to contribute to South Africa's growth.

AGRICULTURE

Agriculture, forestry and fisheries play an important role, not only in terms of feeding the nation, but also in offering formal employment to about 850 000 people. In 2013, there were some 35 000 large-scale farming enterprises and approximately two million

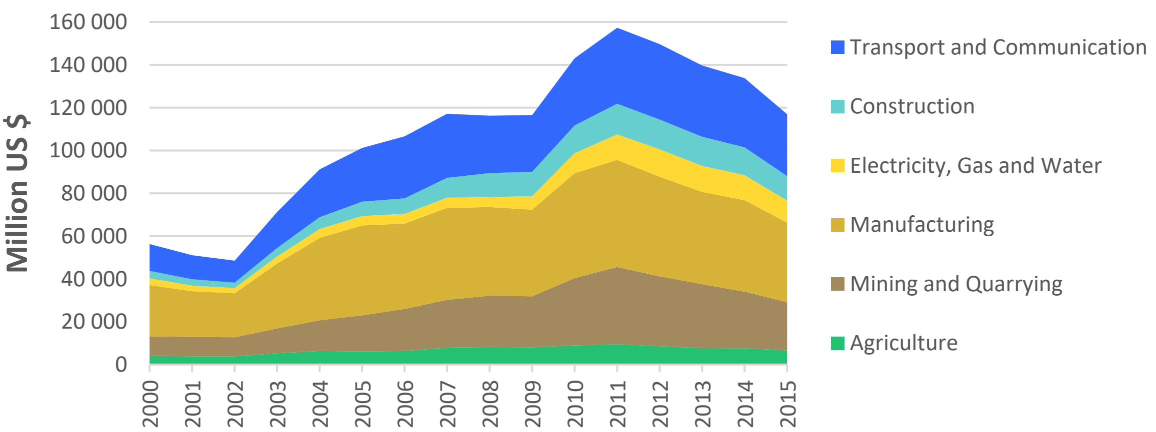


Figure 1: GPD per engineering-related economic activity (42% of the GDP)

subsistence farming households. Although almost 70% of the country is farmland, vast areas are suitable only for low-density livestock farming. Climate–soil combinations leave only 13% of the land suitable for production of rainfed crops. With only 3% considered to be truly fertile land, South Africa falls short of other countries such as India where arable land covers 53% of the country.

Maize is the most widely grown crop, followed by wheat, oats, sugarcane and sunflowers. Agricultural activities range from intensive crop production and mixed farming in winter rainfall and high summer rainfall areas, to cattle ranching in the bushveld and sheep farming in the arid regions.

All of South Africa's irrigable land is already under irrigation, and expansion into unsuitable areas is a concern as this will do little to increase yield but will increase water demand. Already, almost 50% of the country's water is used for agriculture. There is also concern that farming methods, monoculture, use of artificial input and excess watering are not sustainable, and changes in approach are required to ensure ongoing productivity and food security. The need to cater for issues such as climate change, population growth, skills shortages and changes in consumer needs must also be factored into future strategies.

Subsistence farming

Subsistence and smallholder farming are mostly found in the Eastern and Northern Cape, KwaZulu-Natal and Limpopo. Plots are extremely small, usually not more than 1.5 ha per household, but a substantial proportion are less than 0.5 ha. These households produce agricultural goods for their own consumption and have limited access to basic services such as water and electricity. Studies have shown that their production has reduced, and they depend increasingly on market purchases. A significant number of people in agriculture have no schooling and no income, and are older than 45 years of age.

As comprehensive workplace training for graduates has also fallen away, smallholders in particular complain that those who arrive to give advice have inadequate knowledge or experience to be able to offer meaningful assistance.

Government intervention should therefore focus on developing general agricultural skills, facilitating access to markets and providing funding, targeting especially rural provinces. Understandably, the Agriculture Sector Education Training Authority (AgriSETA) lists agricultural engineering as a skill needed, with specific focus to be placed on technologies suitable for small-scale farmers, e.g. relevant and post-harvesting techniques related to the processing and storage of produce.

The Comprehensive Agricultural Support Programme (CASP) lists the need to provide smallholder farmers with farm equipment, fencing, fertilisers, seedlings and other essentials, and to strengthen extension services. Agri-parks are being established in collaboration with the Department of Rural Development and Land Reform to provide agro-processing facilities, logistical services and access to markets.

Commercial farming

The commercial sector is self-sufficient in virtually all major agricultural products and is a net food exporter. The main export products are citrus and deciduous fruits, wines and flowers. Vast irrigation schemes are in place covering about 45% of the total annually irrigated area of approximately 1.3 million ha. The commercial sector is highly mechanised and post-harvest facilities are well developed. In 2006 some 300 grain silos, seen on the skyline in many parts of the countryside, provided bulk storage capacity of 16.9 million tons. Packing and processing takes place on many farms and the sector is in the fortunate position of having a good national road network for transport logistics to markets, although there are challenges on some provincial and rural roads, where reduced or no maintenance has become a problem over recent years. Handling facilities at ports also cater for agricultural products such as sugar, and refrigeration facilities for perishable goods.

In terms of superlatives, South Africa in the eighth-largest wine producer, the tenth-largest producer of sunflower seeds, and the thirteenth-largest producer of citrus in the world. Tobacco is also an important crop, which involves commercial and small-scale farmers situated in Limpopo, North West, Mpumalanga, and Eastern and Western Cape. A substantial portion of their production is exported, and the balance feeds the manufacturing sector.

Clearly, the success of commercial agriculture relies not only on farming methods, but also on the availability of a range of engineering practitioners. A survey of the agricultural sector in mid-2018 showed that agricultural, along with civil, industrial and mechanical engineering practitioners, were involved in a range of activities, including irrigation, mechanisation, structures, soil, water, environmental and system management, and food and process engineering.

Large numbers of agricultural engineers and extension officers were employed in the Departments of Agriculture and Water Affairs and Forestry to provide agricultural support until the early 2000s, after which the numbers dropped, due to restructuring and reduced budgets. These Departments made generous allocations towards bursaries and offered comprehensive graduate training. With reduced demand, two universities were forced to close their Agricultural Engineering departments and the agricultural engineering national diploma was no longer offered. As a result, fewer than 20 agricultural engineers now graduate per year, through the University of KwaZulu-Natal.

Commercial farmers rely on their own sources of information such as input from suppliers, agricultural cooperatives, farmer organisations and the internet.

The Agricultural Research Council (ARC) has over many years offered support to both the commercial and subsistence sectors, developing many innovations, including fuel from sunflower seeds, biomass digesters and improved irrigation systems, among others. They also offer design support and advice across the entire sector, tackling issues such as insect infestation, all the way to designing dams and irrigation systems.

Funding for pure research is constantly being reduced and the ARC has become more of a consulting service provider, with pockets of excellence existing mostly around established researchers, many of whom are approaching retirement age.

Forestry

South Africa has developed one of the largest man-made forestry resources in the world. These plantations cover more than 1.4 million ha, with exports accounting for 35% of the total turnover of forestry products. Two private pulp and paper manufacturers, discussed under *Manufacturing*, rank among the largest companies of their kind in the Southern Hemisphere.

Fisheries

The South African coastline covers almost 2 800 km, linking the east and west coasts of Africa, and is home to 10 000 species of marine plants and animals. Commercially exploited marine life includes hake, anchovy, sardine, horse mackerel, tuna, snoek, rock lobster and abalone in the west, and various line-fish and squid in the east. It is recognised that fish production can be substantially increased through aquaculture, and a large programme has been put in place through Operation Phakisa to increase production from 4 000 tonnes per year to 20 000 tonnes per year by 2020. South Africa is currently the largest fish trader in the region, with exports far exceeding imports.

MINING AND QUARRYING

As outlined in the introduction, South Africa is a leading producer in world terms of platinum group metals (PGMs), diamonds, iron ore and gold and holds a large portion of the world's manganese and chrome. It is also a major producer of zircon, rutile and ilmenite and is rich in coal, nickel, phosphates, uranium, copper and rare earth minerals. Locally, important deposits include natural gas, salt, tin and antimony. Hard rock for quarrying e.g. for road-making materials is plentiful. There are no deposits of oil or bauxite.

Many deposits remain untapped as large portions of these reserves are found several kilometres underground, which means that innovative and state-of-the-art extraction techniques are needed. This has led to South African mines being at the forefront of extractive techniques and technological innovations, particularly in gold mining.

South Africa also has many large opencast mines, the deepest of which is over 800 m and requires careful management of the mining process and machinery used.

Apart from its prolific mineral reserves, South Africa's strengths include a high level of technical and production expertise, and comprehensive research and development activities. The Chamber of Mines Research Laboratories have been at the forefront of research since inception. Gauteng-based universities and universities of technology (UoTs) have produced mining and metallurgical engineers, technicians and technologists, who with the experience gained in South African mines, are sought after worldwide.

South Africa also boasts world-class primary processing facilities, including beneficiation, smelting and refining of gold, platinum, carbon steel, stainless steel and aluminium.

South Africa's mining industry is continually adapting to local and international conditions and makes a significant contribution to economic activity, job creation and foreign exchange earnings. There is a significant mining support and manufacturing industry making the country largely self-sufficient in machinery and equipment, which is also exported.

The industry does, however, face many challenges in addition to the depth of mining, which include diminishing ores grades, increasing competition internationally and reducing commodity prices. These require improved productivity and an increasing degree of automation, which will require investment. More stringent health, safety and environmental requirements have also increased the cost of mining.

In 2017, mining contributed 8% to the GDP (down from 21% in 1980).

Proposed policy changes including increased royalties, changes in licencing, labour and ownership requirements have further affected the appeal of the sector, with investors moving to more attractive mining environments. This is of concern, considering the enormous potential of industry to contribute to the country's economic well-being.

MANUFACTURING

South Africa has an established, diversified manufacturing base which employed 1.79 million people and contributed 13% to the GDP in 2017. The country has by far the largest manufacturing sector in the region – more than five times larger than the manufacturing sectors in Angola or the DRC. It demonstrates the sophistication of First World markets, supported by excellent transport and communications infrastructure.

South Africa is largely self-sufficient in the production of food and fast-moving consumer goods (FMCGs), with imports representing name brand or luxury products or cheap alternatives. The sector has, however, been declining since the late 1990s to early 2000s and has shed some 400 000 jobs since 2008. This can be attributed to some extent to competition from countries such as China, Vietnam and Bangladesh, after the South African market was liberalised. The share of the various sectors is shown in Figure 2.

To become a major world player, it will be necessary to enhance the roles played by advanced technologies, policy, infrastructure and high-level skills. The Industrial Policy and Action Plan (IPAP) 2017/2018–2019/2020 aims to address many of these issues, including technology transfer, aligning policies, cutting red tape, raising funding, offering incentives, encouraging beneficiation, use of technology, increased exports and cracking down on illegal or substandard imports.

Activities requiring the use of engineering skills, in each of the subsectors, are described below.

Food, beverages and tobacco products

The total output in the food and beverages manufacturing sector has grown steadily over the last two decades and is relatively unaffected by economic fluctuation. The government has identified agro-processing as a critical area of growth, with the potential to create a million possible new job opportunities. No fewer than 24 food-manufacturing firms are listed on the Johannesburg Stock Exchange (JSE).

South Africa is self-sufficient in food production, with the bulk of food being produced from local raw materials. The sector consists of 12 downstream subsectors, including meat processing; dairy products; preservation of fruit, vegetables, nuts and herbs; canning and preserving fish; fruit canning and jams; vegetable and animal oils and fats; grain mill products; sugar mills and refineries; chocolate and sugar confectionery; prepared animal foods; bakery products and other food products, such as starch and starch products; and ready-made meals.

There are numerous sugar, flour, rice and other types of mills, with a total of 345 employers registered in the milling sector. Waste and by-products of many processes are used in the production of animal feed.

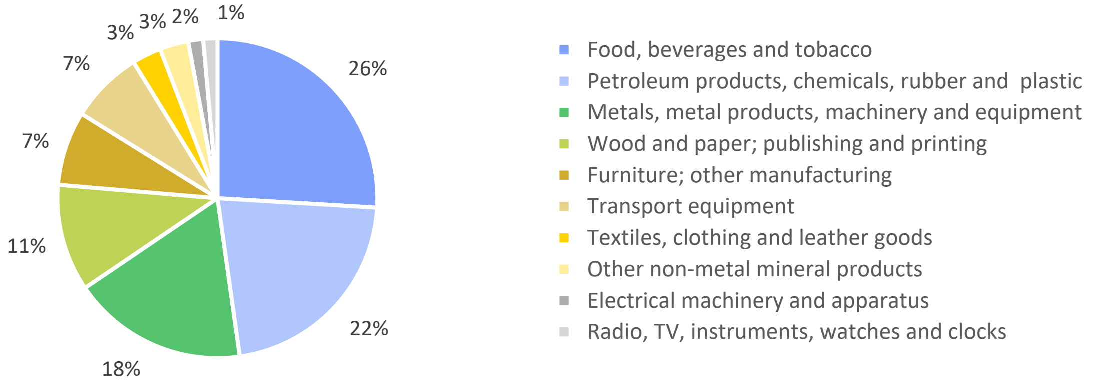


Figure 2: Contribution to manufacturing per industry in 2016 (StatsSA)

The manufacture of oils and fats from soybeans, sunflower seeds, canola, and peanuts is on the increase.

A range of sparkling and still beverages, including soft drinks, sports drinks, energy drinks, bottled waters, flavoured and/or enhanced waters, ready-to-drink teas and coffees, and dairy-based beverages, are produced locally. On-the-go consumption continues to grow, as more consumers eat and drink outside of their homes, which has resulted in the development of many new products.

Liquor production includes beer, wine, spirits and flavoured alcoholic beverages, and was valued at an estimated R106.1 billion in 2016. Beer sales dominated the sector, accounting for 56.1% of the value of liquor sales and nearly 80% of the volume. South Africa's alcohol consumption rate has climbed in recent years, making the country the third-largest consumer of alcohol in Africa and, according to the World Health Organization (WHO), the nineteenth biggest consumer in the world.

Cigarettes, pipe tobacco and snuff are produced for local consumers and the export market.

World-class infrastructure, counter-seasonality to Europe, vast biodiversity and marine resources, and competitive input costs make the country a major player on world markets. In the current economic climate, more emphasis has been placed on optimising existing resources and improving productivity. However, skills are frequently not aligned to new technologies. Advanced engineering skills in operations and maintenance are required, which are hard to find.

Textiles, clothing and leather

Through technological developments textile production has evolved into a capital-intensive industry, producing synthetic fibres in large quantities. The local clothing and textile industry has grown to offer the full range of services, from natural and synthetic fibre production to non-wovens, spinning, weaving, tufting, knitting, dyeing and finishing. The sector had been under intense pressure for well over a quarter of a century, but prospects have improved with various interventions. In 2017, the clothing and textile sector employed 95 000 people. The larger firms require high-level skills such as process/industrial engineers (at NQF Level 8) who design processes and process improvements for labour-intensive activities such as clothing.

In 2016, South Africa manufactured 66.8 million pairs of shoes in some 190 enterprises. The demand, however, is for 240 million pairs. As part of IPAP, to promote the leather industry, support has recently been given to opening 22 new factories.

Timber, pulp, paper and packaging

Timber is supplied as sawnlogs, veneer logs, pulpwood, mining timber, poles, matchwood, charcoal and firewood. The forestry sector, including downstream processing, contributes between 1% and 2% to the total GDP, but 10% to 12% to manufacturing GDP, with pulp and paper being the most significant contributor. The sector contributes to rural employment and export earnings. Some 25 large enterprises in pulp, paper and packaging would employ engineering practitioners.

Plastics, chemicals and other non-metallic mineral products

The plastics sector contributed about 16.5% of the manufacturing output in 2016 and employs 60 000 people. The range of plastic products includes packaging, houseware and furniture, construction materials and agricultural products, among others. Plastic is also used in the manufacture of appliances, electronic devices, fittings and trimming. The packaging market is the largest consumer of plastics.

The automotive industry is planning to increase the plastic content in electric vehicles by around 25% to enable a necessary saving in vehicle weight – this bodes well for the plastics sector. A vibrant tyre industry benefits from South Africa's well-developed automotive sector, although competition from imports and second-hand tyres is a big challenge.

Recognised barriers to growth in the plastics sector are a skills shortage and slow technological upgrading, as well as high competition from imports.

The chemical industry contributes around 5% to the GDP and approximately 22% to manufacturing sales. In 2015, employment was estimated at 165 782 people. Products in this sector include coke and refined petroleum products, basic chemicals, explosives and fertilisers, fast-moving consumer goods (such as soaps, household and beauty products), non-metallic minerals, glass and glass products, speciality chemicals and surface coatings (such as paint and other chemicals), and man-made fibres. Growth has been slow, linked to the national slowdown in demand. A chemical SEZ is being considered to stimulate growth in the sector. A vacancy rate of 13.5% was reported for chemical engineers in 2015.

South Africa has 21 cement and grinding plants and an installed capacity for cement production of 20 million tons. The current demand is at around 13 million tons. This means that at an annual compound growth of 2.5%, South Africa will only run out of capacity by 2030.

Pharmaceuticals

Two multinational companies dominate domestic pharmaceutical production. The sector almost exclusively produces generic products, but relies on imported raw materials. In 2013, generics accounted for 63% of the private pharmaceutical market and an 80% market share in the government's pharmaceutical use. Although pharmaceutical exports were valued at R4.9 billion in 2015, the import of raw materials and patent medicines made medical products the fifth-largest contributor to the country's trade deficit.

The development of new product lines, including vaccines, ARVs, TB and biological medicines, coupled with incentives, is being considered to increase local production. The pharmaceutical sector was forecast to grow at 6.6% over the period from 2016 to 2021, in tandem with the demand for medicines.

Computer, electronic and optical products, and electrical equipment

The South African information and communication technologies (ICT) sector is the largest and most advanced in Africa, and is characterised by technology leadership, particularly in the field of mobile software and electronic banking services. The country's established and sophisticated indigenous ICT and electronics sector comprises more than 3 000 companies, with access to cutting-edge technologies, equipment and skills. Software developers are recognised for their innovative solutions.

South African companies are global leaders in smart- and pre-payment metering, revenue management and fraud prevention systems, and in the manufacture of set-top boxes (signal decoder), all of which are exported worldwide.

Substation equipment, transformers and transmission line components are also manufactured locally and much electronic equipment is developed by innovative entrepreneurs in the areas of monitoring, safety and security systems, renewable energy control equipment and the lighting industry.

Metal industries, machinery and equipment

The subsector has access to vast natural resources and represents roughly a third of all manufacturing. The whole iron and steel value chain is in place, from smelting to producing a range of end-products, including structural steel, pipes, cables, wire, fasteners, cans (almost 200 billion cans of food are produced each year), vehicles, rolling stock, planes and boats, machinery, equipment, parts, tanks and appliances, to name but a few.

Bauxite, the raw material for aluminium smelting, which is not found in southern Africa, is imported mainly from Australia as partially processed alumina. It is processed in Richards Bay and Pietermaritzburg (and Mozal in Mozambique). The smelting process uses high volumes of electricity, which at the time of the smelter developments was available at extremely low rates from Eskom. The local smelters contribute 2% to export revenue, making it the ninth-largest export from South Africa.

Foundries, tool-, die- and mould-making companies are also forecasting growth.

The automotive industry is one of South Africa's most important sectors, with many of the major multi-nationals, such as BMW, Ford, Daimler-Chrysler, Isuzu, Toyota and Volkswagen, using South Africa to source components and assemble vehicles for both the local and international markets. Component manufacturers such as Arvin Exhaust, Bloxwitch, Corning, Senior Flexonics, have also established production bases in the country.

In 2013, the Department of Trade and Industry (dti) introduced the Automotive Production Development Programme (APDP) and the Automotive Masterplan 2020 with the intention of increasing the volume of cars manufactured in South Africa to 1.2 million annually by 2020, and to diversify the automotive components chain. The intention is to grow component manufacture from the current level of 37% to 60% by 2030.

The sector is expected to be 100% automated in the future, with body shops run by robots. Skills able to maintain this equipment and interact with technology are therefore important. Posts for industrial engineers and mechanical and electrical technicians are reported by the Manufacturing, Engineering and Related Services Sector Education and Training Authority (merSETA) as being difficult to fill. The automotive industry looks increasingly attractive, on the back of rapid urbanisation, improving infrastructure and road connectivity.

The development of rolling stock in South Africa has been given a boost with a R59 billion contract to build 600 new commuter trains over a 10-year period, starting in late 2018. The contract will also support the development of local manufacturers who will produce 65% to 70% of the parts by volume locally.

On the coast, the boat and shipbuilding sector has created over 4 500 jobs, with R3.42 billion in tenders awarded to local companies.

A niche market for South Africa has been in aero-space and defence, which develops and manufactures artillery, munitions, missiles, aerostructures, unmanned aerial vehicle systems and aircraft, using high-end technology. This market feeds not only the National Defence Force, but also markets worldwide.

Map to a Million

A detailed investigation into the challenges and opportunities in manufacturing, carried out in 2017, identified high input costs, lack of investment, high electricity costs, poor infrastructure, overly liberalised trade terms and the lack of technical skills as being some of the many barriers to growth. In addition, with manufacturing based largely in Gauteng, the transport logistics in terms of distances to ports, and the high cost of port tariffs affect the overall competitiveness of exports.

An ambitious plan with many key recommendations has been developed to create one million jobs over the next 10 years. The many recommendations include addressing trade tariffs, simplifying doing business, making local products attractive and supporting large manufacturers to expand, with the proviso that they develop SMMEs. Most importantly, in terms of engineering skills, the report suggests that *'industry needs to improve fundamental skills of running a factory, planning projects and maintenance, optimising inventory and run lengths while meeting customer requirements'*. This is a perfect description of the role an industrial engineer plays.

When responding to the engineering skills survey carried out as part of the Numbers and Needs Study, 35% said they were unable to find suitably trained engineering practitioners, citing lack of experienced staff and poorly prepared graduates as challenges. Of concern was the fact that the theoretical training was often not relevant to the sector and graduates had not had any practical training but wished to earn high salaries. The sentiment expressed by one respondent captures the challenge *'the youngsters don't understand that the only way to become GOOD engineers is by being patient and gaining as much experience as possible'*. Others lamented the move away from the more applied training given to technicians in the past, to generic theoretical training in the universities of technology.

Only 4% offered graduate training and mentorship, which is of great concern, as engineering degrees are not designed to include practical training – this is the domain of the workplace. It is critical that the sector develops one- or two-year graduate development programmes to orientate and develop technicians and engineering managers of the future. To address the gap, 8% employed foreign skills, the majority using skills from Zimbabwe. Five per cent of respondents also noted the difficulty in finding good artisans such a boilermakers, sheet metal workers, welders and electricians.

ELECTRICITY, GAS AND WATER

Electricity

Eighty-five per cent of the population has access to electricity, made up of 90% of the urban population, and 77% of the rural population in 2013. This is a great improvement from 36% in 1994.

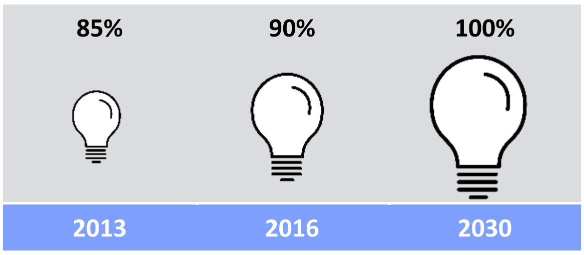


Figure 3: Target dates for access to electricity

The Universal Access to Energy Strategy aims to have 90% of homes electrified by 2030, with the remaining 10% being connected through off-grid solutions (primarily solar home systems).

South Africa makes use of a number of technologies to generate electricity as shown in Figure 4.

With the growth of the economy after 1994, the demand for electricity outstripped supply and in 2008 the country experienced rolling blackouts. Two major developments have since taken place. The first unit of Medupi Power Station came online in 2015, adding 796 MW to the national grid, and an additional unit was stress loaded in 2016. When fully up to production the plant will generate 4 800 MW. The first unit of the Kusile Power Station came online in May 2017, providing 800 MW. An additional five units will be completed by 2021 and will generate a further 4 000 MW. Initially, there will be an excess of power which will be sold to neighbouring states through the South African Power Pool (SAPP). In addition to these coal-fired power stations, there are a number of wind farms being constructed or

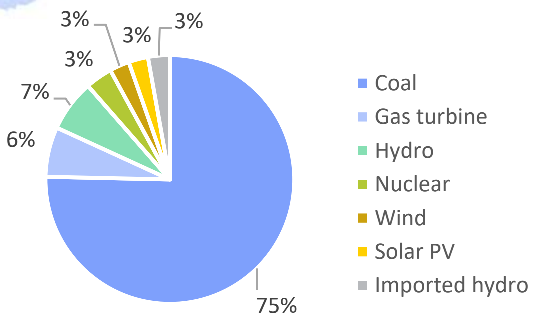


Figure 4: Energy sources for generation plants

tendered on, with an anticipated generation capacity of 727 MW. These are scheduled to be completed during the course of 2019.

Eskom has a monopoly over power plants and transmission, and is the sole generator and purchaser of electricity in South Africa. Independent Power Producers (IPPs) may generate a maximum of 30% of the country's electricity input, but it must be sold to Eskom to transmit.

Eskom generates and transmits to major industries and municipalities which handle distribution to consumers. There was a long period during which the structure of the distribution sector was being debated, with consideration being given to regional distribution authorities. In anticipation of handing their infrastructure over, municipalities generally only dealt with emergency repairs and not routine maintenance and upgrades. When it was finally decided to retain the current structure, municipalities found themselves with a substantial maintenance backlog, from which many have not yet recovered. Although Eskom has comprehensive training programmes, the same is not true of municipalities, which now find themselves with limited capacity to refurbish and further develop their infrastructure.

Oil and gas

Approximately 60% of crude oil is imported, with 50% of refined products being produced locally and 10% being imported. The remaining 40% comes from Sasol, which produces 35% of refined products through a coal liquefaction process, and 5% comes from PetroSA, which employs a gas-to-liquid refinement process, with the gas being extracted from the Bredasdorp Basin, south-east of Cape Town. Most of South Africa's natural gas is imported from Mozambique through a joint venture between iGas, Sasol and Companhia Mocambicana de Gasoduto SARL.

According to the IRP, the dependence on coal is expected to decline in the medium term, creating space for alternative fuel sources, such as oil and gas, to meet the demand. Fracking in the South African Karoo holds potential for huge local natural gas and oil reserves, reportedly one of the largest reserves in the world. If developed, the reserve could provide South Africa with 400 years of energy and export opportunities. However, the presence of dolerite dykes presents difficulties in drilling and the construction of wells. There are additional significant ecological issues with fracking in the Karoo, which are holding development into this sector back as new regulations need to be developed.

Water and sanitation

In 2015, some 91% of the population had access to safe drinking water, made up of 99% of the urban population and 76% of the rural population.

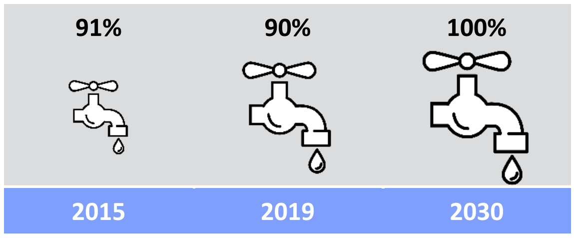


Figure 5: Target dates for access to safe drinking water

The same was not true of sanitation where only 80% of the population had access to improved sanitation, made up of 92% of the urban population and 60.5% of the rural population.

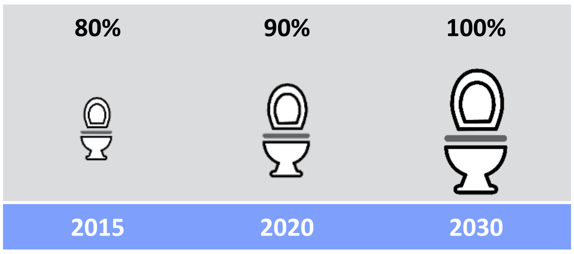


Figure 6: Target dates for access to improved sanitation

Although the number with access to water sounds high, supplies are not reliable. It is considered that only 65% have a reliable supply, and the quality of raw water continues to deteriorate. Some 56% of wastewater treatment works and 44% of water treatment works are in a poor or critical condition and 11% are considered to be dysfunctional.

South Africa is a water-stressed country. Based on projections, by 2030, the water deficit could be between 2 700 and 3 800 million cubic metres per year, a gap of about 17% of available surface and groundwater. Some 35% is lost through leaks in municipal networks.

To balance supply and demand will require a 'Business Unusual' approach – including reducing the demand by improving efficiency, adopting new technologies and reducing losses, particularly in the agricultural and municipal sectors.

According to the NWSMP, policies will be put in place to limit demand, address losses and increase supply. Developments will include the Lesotho Highlands Water Project II (described under *Lesotho*) to augment Gauteng and Free State supplies, the Voëlvlei Dam to augment supplies to Cape Town, and the Smithfield Dam and a pipeline for eThekwini and the Lower uMkhomazi Scheme on the South Coast. Several smaller developments are also planned, and the use of groundwater and recycled water will be increased. Desalination schemes are planned along the coast and in Gauteng to process acid mine water. A total of R33 billion per year will be required for the next 10 years for these developments.

The Department of Water and Sanitation (DWS) is the custodian department. Utilities under the DWS include the Trans-Caledon Tunnel Authority (TCTA), which is the construction unit for major capital projects and the water boards. There are eight Water Boards that provide water to the metros, districts and local municipalities in their vicinity and, in some instances, to major industrial users. Municipalities handle the distribution.

An important goal of the NWSMP is to develop a programme for recruiting and retaining experienced technical and managerial staff with technical qualifications in all these structures. This is critically important, as experienced engineers have left these structures over the years and have largely been replaced with junior technicians.

TRANSPORT AND COMMUNICATION

NATMAP 2050 recognises that transport is the heartbeat of the economy and has presented a comprehensive, multi-modal plan which provides a sustainable framework not only for transport, but also for providing infrastructure and services. The plan was approved by Cabinet on 19 October 2016. The plan recognises the considerable challenges of road safety, inefficient freight handling and ageing infrastructure, and aims for economic competitiveness through seamless multi-modal trade corridors and safe, affordable and accessible modal options for passengers. Substantial developments are planned, as discussed below and listed under *Construction*.

Roads

South Africa's road network, at 750 000 km, is the tenth-longest in the world. It comprises 158 124 km of paved roads, the balance being unpaved and unproclaimed roads, as shown in Table 2. The national roads, a total of 21 946 km, of which 2 952 km are toll roads, fall under the South African National Roads Agency Limited (SANRAL).

These roads carry the bulk of freight transport. SANRAL has contracts in place to cover routine maintenance for every kilometre of its network. The same is not true of provincial and municipal roads and in many provinces, large lengths of roads are in poor condition and, in some cases, are in a state of disrepair.

Table 2: Length of roads under each authority in South Africa

AUTHORITY	PAVED	GRAVEL	TOTAL
SANRAL	21 946	0	21 946
Provinces - 9	46 805	226 273	273 078
Metros - 8	51 682	14 461	66 143
Municipalities	37 691	219 223	256 914
TOTAL	**158 124**	**459 957**	**618 081**
Unproclaimed*		131 919	131 919
ESTIMATED TOTAL	**158 124**	**591 876**	**750 000**

*Unproclaimed estimated road length = Public roads not formally gazetted by any authority

The NATMAP recognises the importance of a good road network for both commercial and private use, and plans major national developments, along with upgrades and instituting maintenance and asset management programmes. The major projects envisaged include:

- **N2 Wild Coast:** Construction of a new highway
- **Gauteng:** Construction of PWV9 and Class 2 routes in municipalities and many link upgrades
- **KwaZulu-Natal:** New heavy haul route from the N2 to Cato Ridge and Richards Bay to Melmoth
- **Limpopo and Mpumalanga:** Upgrade coal haulage roads
- **Western Cape:** Capacity improvements on various roads (M7, R302, R310, R300), doubling of the Huguenot Tunnel and a bypass around Knysna.

Upgrading of gravel roads in various district municipalities and improving capacity on various lengths of national and provincial roads are also listed, along with the elimination of backlogs in maintenance and implementing routine road maintenance. Improved road signage and the introduction of more intelligent transport systems are also envisaged.

It is estimated that over R200 billion will be required for all these developments, over and above the funds made available from the fiscus each year, largely from the fuel levy, for the continuing programmes of surfacing gravel roads, ongoing road upgrades and road maintenances. As there is no capital available for most of these developments, they cannot commence until the impasse on the tolling of roads has been resolved.

The 'user-pay' principle was established in the National Roads Act, No. 7 of 1998, and has been the method by which the high standard of national, economically important roads have been developed in the past. With the controversy over e-tolling in Gauteng, road development has been negatively impacted as no discussions on future tolling and fund raising can commence until a payment arrangement for the Gauteng roads has been resolved.

In terms of skills, in the past, provinces and large municipalities designed, constructed and maintained infrastructure using inhouse engineering personnel. These functions have now largely been outsourced. As a result, recently recruited staff do not gain experience in these areas, and require significant support to grow into senior planning and management positions.

Rail

Transnet and the Passenger Rail Agency of South Africa (PRASA) are the two largest railway operators in South Africa. Transnet focuses on freight and PRASA focuses on passenger rail in urban areas.

South Africa has an extensive rail network of some 20 986 km, which is mostly narrow gauge. It is the thirteenth-longest network in the world and handles approximately 220 million tons of freight per year. There are two heavy haul export lines: the Sishen-Saldanha ore line, which runs eight 342 wagon trains daily (believed to be longest trains in operation in the world), and the Richards Bay coal export line. Two new heavy haul links are being considered – the South Africa to Eswatini link to provide alternative routes to the ports of Richards Bay and Maputo, and the Waterberg to Botswana coal link. Freight is expected to increase by 159% over the next 30 years. This will increase cross-border traffic by 128% and flows into the port system by 133%.

An efficient, connected regional rail network, seamless border processes, standardised operating processes and standardised training are essential to develop the corridors and improve export and trade opportunities for all SADC countries. The Maputo corridor that links South Africa, Eswatini and Mozambique is the most successful among the SADC countries, and it represents the best example of seamless corridor operation. Transnet plans to expand port and rail infrastructure into other African countries, including Senegal, Liberia, Nigeria, Ghana, Togo, Benin, the DRC and Kenya, to assist with the development of corridors.

Rolling stock renewal and terminal and warehousing expansion programmes are also underway.

Ports

There are eight major commercial ports in South Africa, which focus on different commodities based on locality. This includes bulk exports of coal, magnetite, chrome, iron-ore, liquefied natural gas (LNG), automotives, agri-bulk and the handling of breakbulk and containers.

Figure 7: The recently constructed Mount Edgecombe Interchange, opened in October 2018

(Courtesy: SANRAL)

The Transnet Ports Authority (TNPA) plans major developments in Durban Harbour to increase the berth lengths and the drafts of Maydon Wharf, Piers 1 and 2. These developments will be completed by 2021 and will more than treble capacity. Bulk capacity, including a new manganese terminal, will be created at Ngqura and an LNG terminal and bulk liquid berth will be developed in Richards Bay. The TNPA fleet will be greatly extended with the purchase of additional tugs, pilot boats, dredgers and helicopters.

Loss of skills is, however, recognised as a problem in port management, particularly in terms of logistics, and in the fishing ports where lack of maintenance management has resulted in these ports silting up. Transnet has recognised the need to rebuild skills and has implemented several graduate development programmes in the past few years in both the rail and port sectors.

Airports

South Africa has nine major passenger and freight airports in Johannesburg, Durban, Cape Town, Bloemfontein, Port Elizabeth, East London, Upington, Kimberley and George. Together they handled some 37 807 879 passengers during the 2017/2018 financial year. Most airports were upgraded or redeveloped for the Soccer World Cup in 2010 and all are important in terms of not only business and domestic passengers, but also for supporting tourism. Further upgrades are planned for Cape Town International Airport (CTIA) and OR Tambo International Airport (ORT), Johannesburg, including a realigned runway and terminal development at CTIA, and terminal upgrades at ORT, scheduled for completion by June 2019 and October 2020 respectively.

Renovations and developments valued at more than R400 million are on the cards for the East London Airport to expand capacity, improve security and cater for large aeroplanes such as a B737-800.

The airports are managed by Airports Company South Africa (ACSA) whose expertise in managing airports and support operations has expanded to concessions in India, Brazil and Ghana.

Pipelines

A network of 3 000 km of high-pressure petroleum and gas pipelines traverses the provinces of KwaZulu-Natal, Free State, Gauteng, North West and Mpumalanga. The intake stations are two refineries in Durban and the Sasol synfuel plants at Secunda. The network handles an annual average throughput of some 16 billion litres of liquid fuel and more than 450 million cubic metres of gases. It includes a tank farm, at Tarlton in Gauteng, with a capacity of 30 million litres which is used for storage and the distribution of liquid fuels into Botswana.

Communications

The National Development Plan aims to expand the network infrastructure in the country, making 100% broadband penetration a viable target for 2030. The intention is for South Africa to regain its position as the ICT leader, in terms of cost and quality, in Africa. Long-term goals for the country include ensuring that the government makes use of ICT technologies to engage with the community to improve efficiency and effectiveness.

As of 2016, internet penetration in South Africa totalled 54% of the population, but internet access at home was only 9.6%. Improved infrastructure is required to deliver internet to homes at an affordable level. Fixed-line DSL communication subscriptions are decreasing, with FFTH and business offerings increasing in popularity and availability. The number of houses connected to fibre grew from 89 000 in 2016/2017 to 280 000 in 2017/2018 and it is expected to grow substantially as the 'township fibre' project is rolled out – there are ambitious plans to connect 2.5 million homes and 10 million township residents to fibre broadband within a two-year period.

With 82.4 million mobile device subscribers, accounting for 147% of the population, mobile communications infrastructure caters for more than one mobile device per person. Mobile service

Figure 8: The SKA Meerkat radio telescopes
(Courtesy: SKA South Africa)

availability gives 75% of the population access to 4G/LTE services, and 99% of users have 3G service. In 2016, there were 4.5 million fixed-line telephone subscribers, accounting for 8% of the population.

National infrastructure consists mainly of fibre optic networks and connects all major cities and towns. Networks are managed primarily by Telkom, with additional providers Neotel (acquired by Liquid Telecom), Broadband Infraco, Fibreco, DFA, Sanren, Vodacom and MTN.

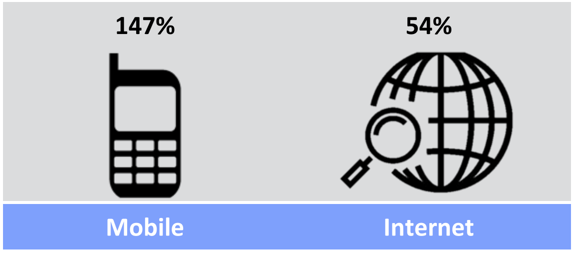


Figure 9: Percentage of population connected to services

There are 10 submarine cables with connection points in South Africa, with four still under construction and the remaining six connecting neighbouring countries and participating in the global network. As it stands, all communication traffic goes through Europe in order to reach the Americas, which is seemingly inefficient. The South Africa to Brazil cable (SABR) is being developed to provide a direct connection to Brazil. A similar cable, the South Atlantic Cable System (SACS) between Angola and Brazil being developed will reduce latency between the Americas and Africa by around 80%.

There are few qualifications available to qualify as a telecommunications professional, with the majority being post-graduate studies once an electrical engineering degree has been attained. The University of South Africa (UNISA) offers a BTech degree in electrical engineering with a core focus on telecommunications.

Considering a different type of communication, the Square Kilometre Array (SKA) is an international initiative to build the world's largest radio telescope, which will eventually cover a square kilometre of collecting area. South Africa was awarded a large portion of the development, which has been constructed in the remote Northern Cape and will become fully operational in 2020.

Satellite dishes positioned all over the world will enable astronomers to monitor the heavens in unprecedented detail and collect data much faster than any system currently in existence. Sophisticated communication systems and Big Data Management Systems are key to being able to collect and interpret the massive volumes of data that will be collected from the far-flung corners of the universe, billions of light years away. Once completed, it is expected that the SKA will generate more data per day than the entire internet. It is hoped that with this data we will finally be able to answer fundamental questions about the laws of nature, and how the universe, and the stars and galaxies contained in it, were formed.

CONSTRUCTION

Construction is important in any country due to its ability to create jobs and develop skills. The

Table 3: Major projects identified, or being planned or under construction

PROJECT		VALUE US$	START YEAR	END YEAR
Energy	1 200 MW concentrated solar power (CSP) projects	$9.4bn	TBD	
	1 GW solar park	$16bn	TBD	
	2 500 MW coal power generation	$4.5bn	TBD	
	4 725 MW photovoltaic (PV) projects	$10.3bn	TBD	
	6 360 MW wind projects	$11.3bn	TBD	
	New multi-product pipeline (phase 1)	$2.5bn	95% complete	
Ports	Upgrade of Port Ngqura	$55.8m	2018	2020
Roads & rail	Construction of the N2 Wild Coast Highway	$830m	2018	2021
	Mixed-use Rosslyn Hub development	$250m	TBD	
	Rehabilitation and maintenance of coal haulage roads in Mpumalanga	$83m	2018	2020
	Sishen–Saldanha Corridor expansion programme	$752m	Under construction	
	Upgrading of the Limpopo and Mpumalanga sections of the R573 Moloto Road	$358m	2018	2020
	Manganese rail and terminal	$1.4bn		2020
Other	Human settlements: Cornubia integrated human settlement	$2bn		2026
	Five mega-cities in Gauteng		Planning stage	
	Various mega housing projects in Gauteng		Being rolled out	

construction sector has gone through boom and bust periods linked to government spending. In the build-up to the 2010 Soccer World Cup the sector was overextended in terms of the huge developments taking place concurrently. Prices were very high due to the need to import additional materials and equipment. However, in 2017 and 2018 the industry struggled through the poor economic conditions, with many companies closing divisions, retrenching staff or going into business rescue.

The major contractors are long-established, listed companies with considerable resources, assets and access to finance. Transformation is a national imperative. Policies are in place that require large contractors to partner with emerging contractors on public sector projects to develop their capacity. The NDP and the National Infrastructure Plan (NIP), along with the Master Plans developed in response to these, list the development of numerous mega Strategic Integrated Projects (SIPs) between 2012 and 2030, but finance is a constraint, hence they are not all listed in Table 3. The roll-out of these projects is overseen by the Presidential Infrastructure Coordinating Commission (PICC) to ensure that any blockages are overcome without delay.

In 2012 when announcing the roll-out of the SIPs, the President stated that the massive investment in infrastructure must leave more than just power stations, rail lines, dams and roads. It must industrialise the country, generate skills and boost much-needed job creation.

In the private sector, major shopping malls, commercial and industrial developments continue. The major projects planned are listed in Table 3.

Housing

The country's housing backlog is currently estimated at 2.1 million. Government has built four million houses since 1994 but with rapid urbanisation the demand for low-cost housing continues. The main challenges are the expropriation and transfer of land, and the need to service new townships, before houses can be built. As the backlog increases rather than decreases and complaints of poor quality developments persist, the Peoples Housing Process seeks to make serviced land and support for self-building available to the urban poor.

The Human Settlements Vision to eradicate backlogs, translates into to providing housing for about 12.5 million people. Funding is made available through metropolitans and provinces to manage housing development.

LOCAL GOVERNMENT

There are eight metropolitan, 204 local and 44 district municipalities in South Africa. The powers and functions are assigned to local government in the Constitution, as shown in Table 4. These are assigned per province. In some provinces, the districts are assigned the road and stormwater functions and the local municipalities the water and sanitation functions, while in others the roles are reversed.

Before 1994, local government consisted of 853 stand-alone municipalities, serving about 14.2 million people. The balance of today's population lived in the Transkei, Bophuthatswana, Venda and Ciskei (known as the TBVC states). There were approximately 20 civil engineering staff per 100 000 of the population. If this were to be extrapolated to all engineering disciplines, the ratio would be approximately 32 per 100 000.

In the new dispensation, 'wall-to-wall' local government was rolled out to cover the whole population. Many small municipalities were merged into larger municipalities, and areas in between these centres also became the responsibility of the new municipalities. It was thought that by combining municipalities, staff could be rationalised and reduced. However, given the vastly increased areas and numbers of people they were responsible for servicing, this was not the case, and there should have been an increase of engineering staff.

The result was that by 2005, there were only five civil engineering staff per 100 000, or eight engineering staff in total per 100 000. An update of the research quoted, carried out in 2015, showed that although the number of engineering staff had increased since 2005, so had the population and the ratio had hardly changed. Of concern, though, is that whereas the early staff composition included engineers, technologists and technicians of all ages, experienced engineers have been replaced by junior technicians. Figure 10 shows the change in experience of civil

Table 4: Engineering powers and functions assigned to local government

Electricity and gas reticulation	Water and sanitation	Roads, public transport
Planning	Stormwater management	Public works (internal)
Emergency services	Solid waste management	Pontoons and jetties, etc.
Airports	Abattoirs	Markets
Billboards and advertisements	Fencing and fences	Cemeteries and crematoria
Beach facilities	Street lighting	Cleansing
Amenities, including sports and recreation facilities		

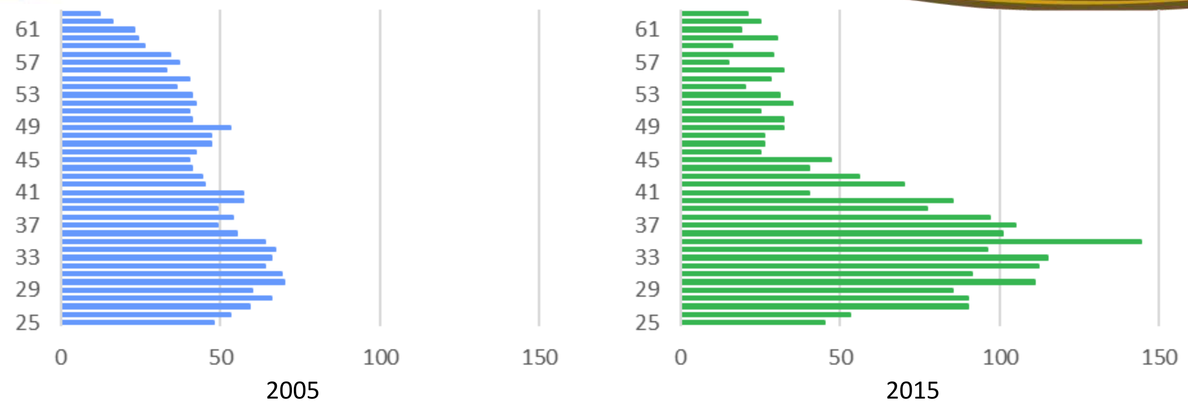


Figure 10: An age comparison of civil engineering practitioners in local government between 2005 and 2015

engineering practitioners from 2005 to 2015 – the number above 45 has almost halved while the number below 39 has almost doubled.

An assessment by the National Treasury in 2018 suggested that at least half of the 257 municipalities are dysfunctional.

The Infrastructure Report Card produced every five years by the South African Institution of Civil Engineering (SAICE) showed the condition of most municipal services outside metros to be at D or E, where E is classified as being *'unfit for purpose'*. Sadly, although inappropriate skills are listed as a challenge, corruption and the lack of revenue collection are key factors that have brought local government to its knees.

EDUCATION, TRAINING AND PROFESSIONAL DEVELOPMENT

Education and training is a vital part of developing engineering capacity. All elements, from teaching appropriate subjects in schools to continuing professional development (CPD), need to be in place to educate and train engineering personnel and ensure that they remain abreast of the latest technology, challenges and emerging solutions.

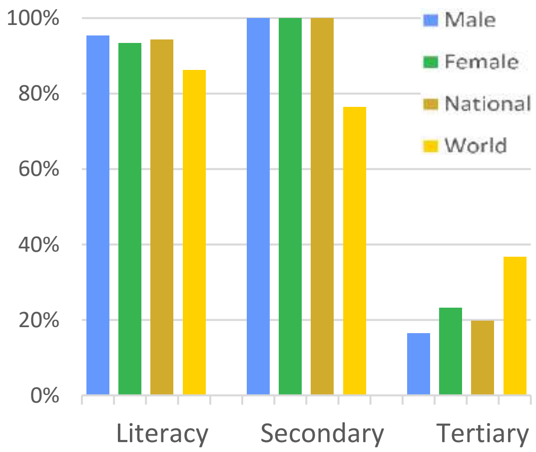


Figure 11: Literacy and enrolment statistics
(UNESCO from 2014 to 2015)

PRIMARY AND SECONDARY EDUCATION

Compulsory education in South Africa starts with primary education which consists of seven years from Grade 1 to Grade 7. Secondary education stretches over five years from Grade 8 to Grade 12.

Education in South Africa suffers many challenges, including crowded classrooms and unqualified teachers. Declining employment conditions and benefits have led to a limited pool of dedicated teachers, most of whom teach in private schools which offer better conditions.

VOCATIONAL TRAINING

Learners may leave school after Grade 9 and enter Technical and Vocational Education and Training (TVET) colleges. Colleges offer a range of training, from short courses, skills programmes, Adult Basic Education and Training (ABET) certificated courses to structured learnerships and apprenticeships for occupations and trades. The Quality Council for Trades and Occupations (QCTO) has been set up to accredit and award qualifications in this space. Students may qualify after completing a higher certificate for admission to UoTs to continue their studies at a higher level if their school results or the complexity of their TVET studies match the admission requirements.

In 2000, South African employers started to pay a skills training levy of 1% of the payroll to a central fund. These funds are dispersed to the National Skills Fund, the QCTO and Sector Training and Education Authorities (SETAs). The SETAs, set up in each sector, are responsible for dispersing funds to those who offer training. The funds have been used for bursaries, learnerships, apprenticeships, and graduate training, among others, and for infrastructure and equipment enhancements where appropriate.

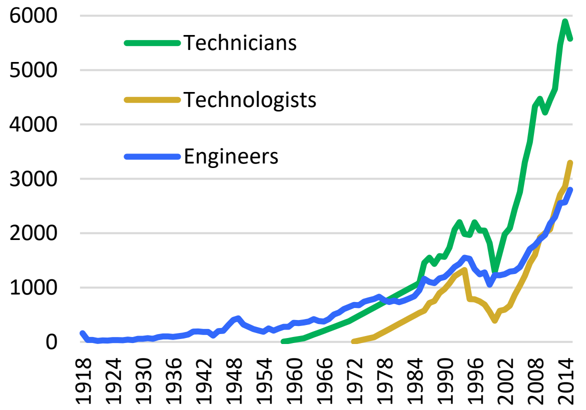


Figure 12: Engineering graduations in South Africa since 1918

To address weaknesses in the training of artisans in the TVET space, a *'Centres of Specialisation'* initiative has been launched, where colleges are being strengthened to train 13 priority trades, recognised as being critical to the SIPs. The scope of the Numbers and Needs Study does not, however, cover artisans. There is confusion about the use of the word 'technician' in trade-specific situations, such as an automotive technician versus a technician trained at an HEI. The Engineering Council of South Africa (ECSA) which is responsible for registering the latter, has elected to refer to them as 'engineering technicians', which is a title protected in terms of the Engineering Profession Act, No. 46 of 2000.

HIGHER EDUCATION

Universities in South Africa are categorised into three types: universities, universities of technology and comprehensive universities.

- **Universities** offer basic formative degrees, such as a BA and BSc, and professional undergraduate degrees such as a BSc(Eng) or BEng, and a range of post-graduate qualifications such as Master's and Doctoral degrees.
- **Universities of Technology (UoT)** offer mainly vocational or career-focused undergraduate national diplomas for technicians, as well as the BTech which serves as a post-graduate qualification for diploma graduates to take on more complex work in a specific subdiscipline in the workplace and work towards becoming a technologist. UoTs offer a limited number of Master's and Doctoral programmes.
- **Comprehensive universities** offer programmes typical of both types of university.

The first engineers in South Africa qualified from the University of Cape Town at the end of 1918. Graduates from the Universities of Stellenbosch and the Witwatersrand soon joined the ranks. After the restructuring of engineering degrees in the late 1940s it was realised that a technician qualification was required, and the first technicians qualified from the Witwatersrand Technical College in 1958.

By the end of 2015, just over 70 000 engineers and 97 000 technicians had been educated in South Africa, and 41 000 technicians had gone on to become technologists after completing a BTech degree. The total number active in 2018 is estimated to be 110 000 to 120 000 allowing for retirement, mortality, and emigration of a substantial portion of the graduates from the 1980s.

After the restructuring of higher education in the early 2000s, 11 universities, six UoTs and six comprehensive universities emerged. In 2014, the number increased with the opening of two more universities, in the provinces of Mpumalanga and the Northern Cape, which previously had no higher education institutions. Engineering qualifications are offered by five universities, three comprehensive universities and UoTs.

UNISA is a unique institution offering qualifications through correspondence. It is the largest open distance-learning institution in Africa and the longest-standing dedicated distance-education university in the world. It enrols nearly one-third of all South African students. The institution became the first public university in the world to teach exclusively by means of distance education in 1946. The School of Engineering and Technology offers national diplomas and BTechs.

Until recently, all higher education engineering qualifications were offered by the public sector, but private universities have entered the space. Monash is the first private university to be offering engineering qualifications, but the first class is yet to graduate, hence NQ in Table 5, signifying None qualified. Table 5 shows engineering graduations in 2015. The graduation statistics per category and institution are shown in Figure 13 and the split by discipline, category and gender is shown in Figure 14.

The output from the higher education sector has increased substantially in the last number of years, but throughput is still low. Considerable investment is needed to strengthen departments and the student experience to address throughput. Interventions required include the development of:

- **Infrastructure,** including more lecture facilities, laboratories with up-to-date equipment, and sufficient personnel and budget to manage and maintain the facilities

- **Academics,** to gain the level of qualifications required and experience in industry
- **Appropriate organograms,** to ensure an adequate number of academic and support staff
- **Attractive packages,** to attract and retain staff and fill the many vacancies that exist (said to be about 30%)
- **Teaching skills,** to ensure that 21st century approaches to teaching students are applied
- **Private sector support,** in the form of visiting lecturers, retired professionals to assist with mentoring and funding for subvention of salaries or additional Chairs
- **Up-to-date curricula,** for qualifications to be relevant to the needs of industry and the country
- **Student support,** including tutoring, buddy systems, summer and winter schools to assist with complex or so-called 'killer' subjects, and access to funding.

Table 5: Engineering graduations in South Africa in 2015

INSTITUTION	Aerospace & Aeronautical	Agricultural	Chemical	Civil	Electrical & Electronics	Industrial	Mechanical & Mechatronic	Mining & Metallurgy
Degree								
North West University (BEng)			78	19	68		136	
University of Cape Town (BSc(Eng))			96	81	85		153	
University of Johannesburg (BEng)				60	67		44	
University of KwaZulu-Natal (BSc(Eng))		12	37	57	41		60	
University of Pretoria (BEng)			81	165	130	111	187	86
University of Stellenbosch (BEng)			30	107	88	90	148	7
University of Witwatersrand (BSc(Eng))	16		105	71	79	20	49	108
BTech								
Cape Peninsula University of Technology			58	58	70	50	137	
Central University of Technology				76	93	139	42	
Durban University of Technology			94	169	92	50	42	
Mangosuthu University of Technology			15					
Nelson Mandela University				18	28	67	20	
Tshwane University of Technology			52	102	234	66	39	126
University of Johannesburg			57	84	109	101	5	120
University of South Africa			36	106	133	42	195	
Vaal University of Technology			68	68	70	60	36	22
Walter Sisulu University					11		13	
National Diploma								
Cape Peninsula University of Technology			124	180	203	60	217	
Central University of Technology				101	164		65	
Durban University of Technology			62	201	242	69	176	
Mangosuthu University of Technology			95	200	258		126	
Nelson Mandela University				63	81	28	49	
Tshwane University of Technology			62	205	341	112	231	61
University of Johannesburg			84	105	142	70	127	145
University of South Africa			38	41	51	35	45	20
Vaal University of Technology			133	84	241	76	168	50
Walter Sisulu University			6	96			44	
Private								
Monash (National Diploma)					NQ			
TOTAL								
Engineer (2772)	16	12	427	560	558	221	777	201
Technologist (3273)			380	681	840	575	529	268
Technician (5577)			604	1276	1723	450	1248	276

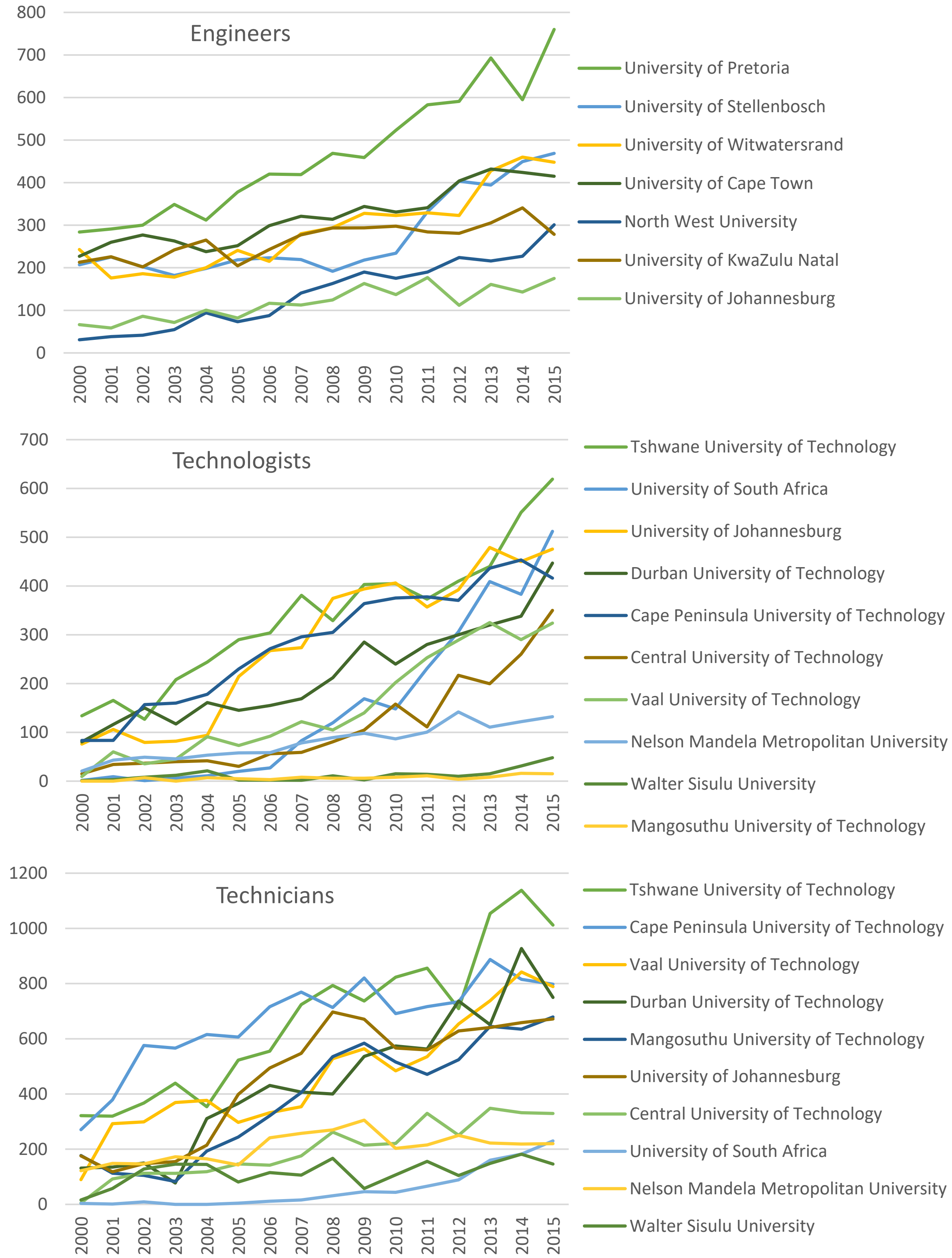


Figure 13: Engineering graduates per category and institution

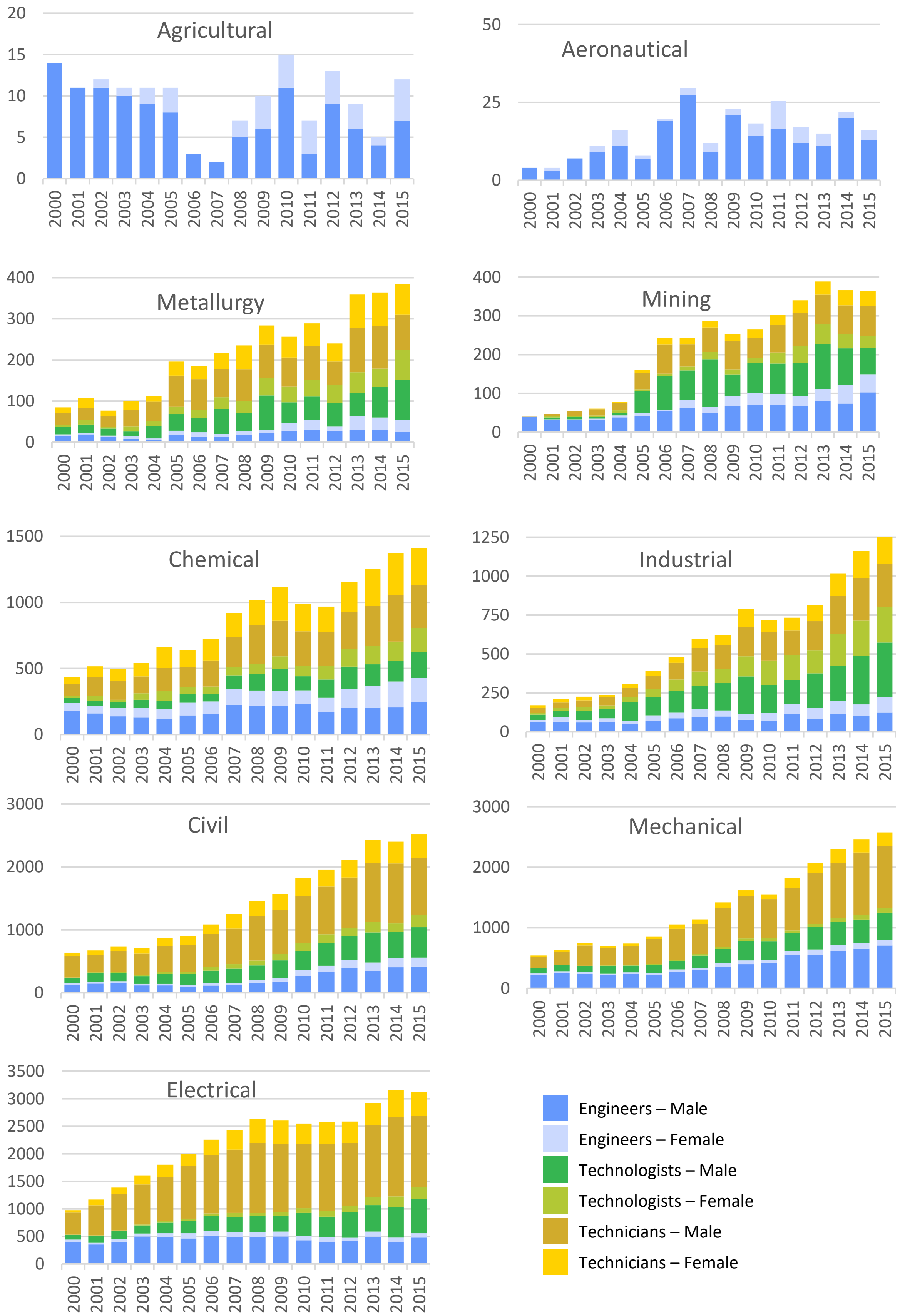


Figure 14: Engineering graduates by discipline, category and gender

The development of academics is more challenging than getting current academics up to speed for existing qualifications. It has been decided to phase out the BTech and replace it with a BEngTech for the training of technologists. There will thus no longer be a two-step process for becoming a technologist. It is intended that the BEngTech will offer more complex theory and practical training, and will allow graduates to eventually articulate to the professional engineer level through post-graduate studies. Lecturers will thus need higher qualifications to be able to teach many of the subjects, and at present few are at the required level. It will take billions of rand and years for lecturers to attain the qualifications required.

It should be noted that many stakeholders have voiced the opinion that there is not enough interaction between the higher education institutions and industry, and that curricula are not sufficiently aligned to industry needs and requirements.

Concerns have been expressed in the past about the absence of teaching on appropriate solutions for rural sanitation and water supply. The need to consider desalination as an option for the future is also necessary, as is teaching about renewable energy options, new technology (such as drones), increasing automation, the Fourth Industrial Revolution, nanotechnology, climate change, etc., to name but a few.

Accreditation

Qualifications in South Africa are registered and assured by the South African Qualifications Authority (SAQA). South Africa has a 10-level National Qualifications Framework (NQF) in which national diploma qualifications for technicians are at level 6, BTechs are at level 7 and engineering degrees are at level 8.

There are three quality councils supporting SAQA, of which the Council for Higher Education (CHE) is assigned the responsibility of developing and implementing a system of quality assurance for higher education. The CHE appoints experts in each discipline to carry out accreditations. In terms of engineering, the CHE has appointed the ECSA, to handle the assessment of engineering qualifications on its behalf.

In 1999, ECSA became the eighth signatory to the Washington Accord and has since become a signatory to the Sydney and Dublin Accords. These Accords define the attributes expected of graduate engineers, technologists and technicians for mutual recognition in signatory countries. Qualifications are assessed against these requirements every six years. South Africa is the only country in the SADC region to have achieved accreditation status.

Student mobility

Due to the comprehensive nature of engineering qualification offerings in South Africa, few students at undergraduate level study abroad. However, the government and various provinces have taken up offers with various Eastern and other countries for local students to study engineering at their institutions. This has meant that students have had to spend a year learning a foreign language before commencing their studies, but their proficiency in the language is generally insufficient to be able to grasp the complex concepts taught in engineering studies, and few have successfully developed sufficient engineering knowledge to be successful back in the South African workplace. The main benefit of employing such graduates is their ability to translate when dealing with consultants and contractors from the country in which they studied.

A further challenge is that few of the qualifications attained are recognised by any of the Accords and returning graduates need to go through the long process of getting their qualifications assessed by ECSA. They are often not rated in the category expected by the graduate. ECSA should be consulted before taking up offers for South African students to follow undergraduate engineering studies outside the country.

GRADUATE TRAINING

Once the tertiary education phase is complete, it is necessary for graduates to receive structured training in the workplace, under professional supervision and mentorship, to develop to the level of competence required for professional registration, and to be able to take on work independently.

As a result of restructuring in many government departments and a slowdown in the economy, the large training programmes of the past had largely been dismantled by the end of the 1990s. Apart from structured training being offered by a few of the larger consulting practices, little support has been offered in the training of graduates for many years. Those graduating struggle to find suitable training opportunities as industry only wishes to employ experienced personnel.

After years of campaigning, the graduate phase of workplace training has been recognised as a phase that requires support and funding. The Candidate Phase as it is now known refers to '*… a period of* workplace-based learning undertaken by a graduate as part of the requirement for registration as a professional in the required professional designation as stipulated by a professional body'*.

In support of this and the training of artisans, the *Training Standard* was gazetted by the Construction Industry Development Board (cidb) in 2013. This can be appended to tenders to ensure that service providers train apprentices, students and graduates on public sector projects. Candidates must have meaningful work assigned to them and have adequate supervision and mentoring. They are expected to have logbooks or training plans and to complete reports on a regular basis, which must be reviewed by the mentor to ensure that progress is being made.

With increasing awareness of the need to develop graduates, more and more companies have started to implement graduate training programmes, or to reinstate training programmes that had been discontinued. The utilities, Eskom and Transnet, are now possibly running the biggest programmes, with 1 000 to 2 000 in training at any one time.

PROFESSIONAL REGISTRATION

The Professional Engineers' Act, No. 81 of 1968, saw the commencement of professional registration, but this was only for engineers.

The Engineering Profession Act, No. 46 of 2000, signalled the establishment of the Engineering Council of South Africa (ECSA) to provide for the registration of professional and candidate engineers, technologists, technicians, certificated engineers and specified categories in the engineering profession, and to uphold standards in the profession. This gave ECSA the responsibility of accrediting engineering qualifications and addressing malpractice in the industry. Registrations per category and discipline in November 2016 are shown in Table 6.

It should be noted that although the largest group of registered professionals are civil engineers, they are not the biggest discipline. As can be seen from Figure 14, many more electrical and mechanical engineers have graduated in the past than civil engineers. However, many more projects require civil engineers to be professionally registered in the interests of public health and safety than those associated with electrical and mechanical engineers.

Over and above being signatories to the Accords, as described in Chapter 3, ECSA has maintained adopted the outcomes-based approach to assessing candidates applying for professional registration, in line with the approach recognised by the International Engineering Alliance (IEA). It has thus been in a position to sign the following agreements:

- International Professional Engineers Agreement (IPEA)
- International Engineering Technologists Agreement (IETA)
- Agreement for International Engineering Technicians (AIET).

These agreements recognise that signatory countries have achieved an international standard of competence for professional registration and empower each member organisation to establish a section of the International Professional Engineers Register, which will allow the mobility of registered professionals between signatory countries. South Africa is the only country in the SADC region to have achieved this status.

Table 6: ECSA registration statistics in November 2016

DISCIPLINE	Pr Eng	Pr Tech Eng	Pr Cert Eng	Pr Techni Eng	Candidate Engineer	Candidate Technologist	Candidate Certificated Engineer	Candidate Technician	Total
Aeronautical	68	0	0	0	52	0	0	1	121
Agricultural	219	12	0	10	89	2	0	2	334
Chemical	1 010	130	0	24	1 078	319	0	124	2685
Civil	6 750	2 557	0	892	2 695	1 708	0	3 636	18238
Electrical	3 348	1 711	467	2 649	1 151	1 091	127	1 989	12533
Industrial	237	34	0	8	244	180	0	92	795
Mechanical	3 353	971	357	317	2 095	948	136	787	8964
Metallurgy	368	65	9	15	155	91	4	38	745
Mining	509	33	133	6	190	46	14	5	936
TOTAL	**15862**	**5513**	**966**	**3921**	**7749**	**4385**	**281**	**6674**	**45351**

VOLUNTARY ASSOCIATIONS AND CONTINUING PROFESSIONAL DEVELOPMENT (CPD)

There are many voluntary associations, broken into two groups: those representing members in disciplines and sub-disciplines recognised by ECSA (see Table 7 for the main disciplines) and those representing companies in various sectors.

To ensure the continuing development of professionals, VAs are given authority, against a strict set of criteria provided by ECSA, to validate courses, seminars, workshops and conferences that would contribute meaningfully to professional development. Sadly, CPD activities are not always offered in the spirit in which they were intended and, in some cases, have become revenue earners without offering much value. Strict monitoring of the quality of material and the knowledge and presentation skills of facilitators needs to be in place.

Table 7: Discipline specific member body voluntary associations

ACRONYM	ASSOCIATION
AeSSA	Aeronautical Society of South Africa
SAIAE	South African Institute of Agricultural Engineers
SAICE	South African Institution of Civil Engineering
SAIChE	South African Institution of Chemical Engineers
SAIEE	South African Institute of Electrical Engineers
SAIIE	Southern African Institute of Industrial Engineers
SAIMechE	The South African Institution of Mechanical Engineering
SAIMM	South African Institute of Mining and Metallurgy

WOMEN IN ENGINEERING

There are several associations that focus on the development of women engineers and scientists, the most substantial being *WomEng* and SA WISE.

WomEng has been working since 2006 to develop the next generation of women engineers and leaders in South Africa. They have scaled their programmes to 14 countries and their energy and passion is in demand worldwide. *WomEng* offers a range of support, including creating awareness at an early age of STEM for girls, engaging with secondary school girl learners to encourage them into the field, supporting female engineering students and assisting those approaching the end of their studies to prepare for the world of work. Once in the workplace, *WomEng* provides a network for female engineers to offer support and encourage professional development and thought leadership.

The Association of South African Women in Science and Engineering (SA WISE) is a dynamic association focused on raising the profile of women scientists and engineers, highlighting and addressing problems faced specifically by women in these fields, and providing leadership and role models for young people wishing to enter STEM careers. An important function of SA WISE is to improve communication among practising women scientists and engineers.

Other groupings include the UJ Group Five Women in Engineering and the Built Environment (WiEBE) Programme, which is committed to making Engineering and the Built Environment careers accessible to all women.

THE WORKFORCE

It is estimated that there is a total of 110 000 engineering practitioners in South Africa, with an age and gender distribution as shown in Figure 15. The estimate has been derived by considering many sources of information. The most comprehensive data is from the Quarterly Labour Force Surveys (QLFS). However, the size of the sample interviewed is small and each quarter the locality of a fifth of the dwelling units in the sample rotates to another area. Results from quarter to quarter are therefore very variable. A three-year average was used from 2014 to 2016 and responses from those with an education level of NQF 5 and below were excluded.

Using data from each VA and asking for their opinion of the percentage of their members in relation the whole industry also gave an indication of the total number, which agreed closely with the QLFS three-year average.

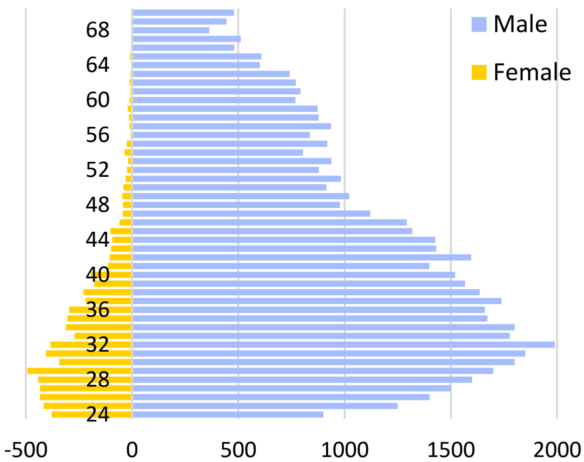


Figure 15: Engineering practitioners in the workforce by age and gender

Table 8: Contractors registered with the cidb, June 2018

GRADE	NUMBER (Total 122 268)	CONTRACT VALUE (Maximum value of contract that a contractor is considered capable of performing)	CONTRACTS COMPLETED (Largest contract completed, during the 5 years immediately preceding the application, in the class of construction works applied for)
1	108 644	R200 000	No requirement
2	4 991	R650 000	R130 000
3	1 840	R2 000 000	R450 000
4	2 391	R4 000 000	R900 000
5	1 229	R6 500 000	R1 500 000
6	1 567	R13 000 000	R3 000 000
7	1 024	R40 000 000	R9 000 000
8	417	R130 000 000	R30 000 000
9	165	No Limit	R90 000 000

THE PRIVATE SECTOR

The main employers in the private sector are consulting, contracting, manufacturing, supplier and mining companies. Lower numbers are employed in small entrepreneurial companies, NGOs, training organisations and other companies where engineering input is required.

Consulting

Consulting Engineers South Africa (CESA) is a voluntary association representing the interests of some 540 companies, who between them employ approximately 24 000 people. In June 2017, they employed 12 181 engineering practitioners, made up of 6 204 engineers, 2 662 engineering technologists and 3 415 technicians. At the time around 70% of firms were looking to employ more technical staff.

CESA member firms are expected to adhere to a professional code of ethics and provide quality and cost-effective professional consulting engineering services. The perception is that non-CESA members do not seem to comply with the same standards and principles as those firms that are members of CESA, and there are concerns about *'below cost'* tendering.

The South African Black Technical and Allied Careers Organisation (SABTACO) is an organisation that represents the interests of black consulting engineers and other organisations practising in technical environments, such as quantity surveyors and architects, among others.

Contracting

There are some 122 890 contactors registered with the cidb, a statutory body set up under the Construction Industry Development Board Act, No. 38 of 2000. Under the Act, the cidb is charged with the responsibility of classifying and registering contractors primarily to enhance delivery, ensure value for money, growth of the emerging construction sector, sustainability, increased capacity and employment opportunities. The range of contractors is shown in Table 8 where Grade 9 represents the largest contractors and Grade 1 the micro contractors. The grades relate to the project sizes that contractors can handle, considering their experience, equipment, access to finance and range of skills employed. Contractors are also classified according to the class of work they can perform, for instance, civil, mechanical, electrical engineering, general building and a range of speciality work.

In 2017, a total of 1 390 000 were employed in the sector, including in consulting and contracting companies, manufacturers of construction materials and suppliers.

There are a number of contracting voluntary associations, including the South African Forum of Civil Engineering Constructors (SAFCEC), the African Builders Association (ABA), the National African Federation for the Building Industry (NAFBI), the National Black Contractors & Allied Trades (NABCAT), the Master Builders South Africa (MBSA) and the South African Women in Construction (SAWIC), all of which represent their members' interests.

In terms of housing, the National Home Builders Registration Council (NHBRC) registers contractors wishing to build homes to ensure that they have the capacity to comply with the prescribed building industry standards as contained in the Home Building Manual.

The rationale is to protect housing consumers from home builders who deliver substandard houses, bad workmanship and use poor quality material. Over 16 000 home builders are registered. All companies registering must have technical capacity, and if not available in-house, must appoint a technical manager to act as an advisor. The highest qualification of many owners and managers is an engineering qualification of some sort.

Manufacturing

The manufacturing sector employed 1.79 million people in 2017. There are hundreds of associations representing the interests of each of the main commodities, associations representing each subsector, and the Manufacturing Circle, which attempts to serve as the voice of the industry, drawing together the major manufacturers from each subsector.

Mining

In 2017, there were 1 775 companies in the mining sector which employed 411 000 people. It is estimated that around 8 000 engineers, engineering technologists and technicians are employed in the sector. The interests of the sector are represented by the Chamber of Mines, rebranded to the Minerals Council South Africa in 2018, while the interests of individuals are represented by the Association of Mine Managers of South Africa (AMMSA), the Association of Mine Resident Engineers (AMRE), the South African Colliery Engineers' Association (SACEA) and the South African Colliery Managers Association (SACMA).

THE PUBLIC SECTOR

Many engineering practitioners are employed in the public sector. Departments employing the largest numbers are shown in Table 9. In addition, engineering practitioners are employed in provincial infrastructure departments, local government and parastatals. With the advent of the democratic South Africa, many departments were restructured in line with the international practice of focusing on the core business and outsourcing the rest. At the time, the infrastructure departments employed literally hundreds of engineers and technicians. Because of restructuring, many engineers were retrenched. In recent years, due to budget constraints in many departments and provinces, posts have been frozen as staff have left. Several structures thus complain about shortages of technical staff.

In post-apartheid South Africa there have been major campaigns to drive transformation throughout the economy. Although this has allowed those with the requisite qualifications to overcome barriers, it has had a detrimental effect on engineering capacity. A programme of early retirement was put in place in the late 1990s which encouraged experienced personnel to leave the public sector to make way for black people and females. As black and female engineering graduates had only started to emerge at that time, it meant that posts were either not filled, or posts previously held by experienced engineers were filled by junior technicians, leaving limited capacity to supervise or mentor new entrants.

Calculations of the workforce at the time showed that even if females were to graduate at a rate of 50% and black people at 89% by 2010, women would only represent a third and black people 66% of the engineering workforce by 2020.

Sadly, targets are blindly set for employment equity which require either a female or a black engineer in a post, otherwise it cannot be filled. There are simply not enough to satisfy these requirements, so posts remain vacant. There is thus limited capacity to offer strategic leadership in terms of long-term planning, budget prioritisation or managing the roll-out of projects and operations and maintenance.

Table 9: Departments employing engineering practitioners

DEPARTMENT/STRUCTURE
Department of Agriculture, Forestry & Fisheries
Department of Communications • Independent Communications Authority of South Africa (ICASA) • South African Broadcasting Corporation (SABC)
Department of Co-operative Governance (COGTA) • Municipal Infrastructure Support Agent (MISA) • All the municipalities
Department of Defence
Department of Energy • Nuclear Energy Corporation of South Africa (NECSA) • Petroleum, Oil & Gas Corporation (PetroSA) • South African National Energy Development Institute (SANEDI)
Department of Human Settlements • Housing Development Agency (HDA) • National Home Builders Registration Council (NHBRC) • Social Housing Regulatory Authority (SHRA)
Department of Mineral Resources • Council for Geoscience • Council for Mineral Technology (Mintek) • Petroleum Agency South Africa
Department of Public Enterprises • Transnet • South African Express • South African Airlink • South African Airways (SAA) • Eskom • Denel (Pty) Ltd • South African Forestry Company (SAFCOL) • Alexkor (diamond mining)
Department of Public Works • Construction Industry Development Board (cidb) • Council for the Built Environment (CBE) • Engineering Council of South Africa (ECSA)

SOUTH AFRICA

DEPARTMENT/STRUCTURE

Department of Science & Technology
- Council for Scientific and Industrial Research (CSIR)
- Agricultural Research Council (ARC)

Department of Telecommunications & Postal Services
- TELKOM
- SENTECH
- Broadband Infraco and the State Information Technology Agency (SITA)

Department of Trade & Industry (dti)
- South African Bureau of Standards (SABS)
- National Metrology Institute of South Africa (NMISA)
- National Regulator for Compulsory Specifications (NRCS)
- South African National Accreditation System (SANAS)

Department of Transport
- Passenger Rail Agency of South Africa (PRASA)
- Rail Safety Regulator (RSR)
- Road Traffic Management (RTMC)
- South African National Roads Agency Limited (SANRAL)
- Cross-Border Road Transport Agency (C-BRTA)
- South African Civil Aviation Authority (SACAA)
- Air Traffic and Navigation Services (ATNS)
- Airports Company South Africa Limited (ACSA)
- South African Maritime Safety Authority (SAMSA)
- Ports Regulator (PR) of South Africa

Department of Water & Sanitation
- Water Research Commission (WRC)
- Trans-Caledon Tunnel Authority (TCTA)
- East Rand Water Care Company (ERWAT)
- Water Boards

Economic Development Department (EDD)
- Industrial Development Corporation (IDC)

Although salaries are reasonably competitive and, in some structures, higher than in the private sector, the lack of authority afforded to engineering professionals in terms of leadership and decision-making does not attract experienced engineers of any colour or gender into the sector. Technical staff complain of having their professional decisions overruled by politicians, supply chain management, or the finance and HR departments.

It has been recognised that technical staff are needed and the Occupation Specific Dispensation (OSD) was introduced to offer higher salaries to registered professionals in technical posts in national and provincial departments. This has, however, had unintended consequences. The allowance has not been extended to managers in technical departments, hence engineers do not apply for these posts, and management decisions on engineering matters are made by non-technical personnel, which in many cases is problematic.

MIGRATION TRENDS

Analysis of the United Nations Population Division statistics for 2015 shows a net gain of professionals in South Africa. Zimbabweans represented the largest group at 16.7%, followed by Lesotho at 6.6% and Namibia at 5%. Some 32% came from all the other southern hemisphere and developing countries together, termed ‘Other South’ by the United Nations. Thirty-five per cent of professional emigrants moved to the UK & Northern Ireland, 25% moved to Australia, 10.9% to the USA and 10.2% to New Zealand. With the worsening economic conditions since 2015, emigrations are on the increase.

ENGINEERING NUMBERS AND NEEDS

Considering the unique position South Africa finds itself in, with mining earning considerable foreign currency, the agricultural sector being able to feed the nation, the manufacturing sector being the envy of the continent, and First World infrastructure in the major centres, it is clear that the country owes a debt of gratitude to many dedicated engineering teams dispersed throughout the economy. They are also to be found in non-engineering sectors, such as management and finance, where they influence spending decisions on development, among others.

Combining all the data, and considering estimates from years of QLFSs, it would seem that there are approximately 110 000 engineering practitioners in South Africa, as shown in Table 10.

Considering the reduction in public sector engineering staff, the major developments planned and the need for ongoing operations and

Table 10: Estimated numbers of engineering practitioners in the engineering workforce

SECTOR	ESTIMATED NUMBER
Academia and research	2 000
Agriculture	500
Consulting	14 000
Contracting	9 000
Graduates in training	3 000
ICT, systems and telecommunications	9 000
Local government	5 000
Manufacturing and suppliers	34 000
Mining	8 000
Miscellaneous and NGOs	5 500
National government	3 500
Parastatals	13 000
Provincial government	3 500
TOTAL	**110 000**

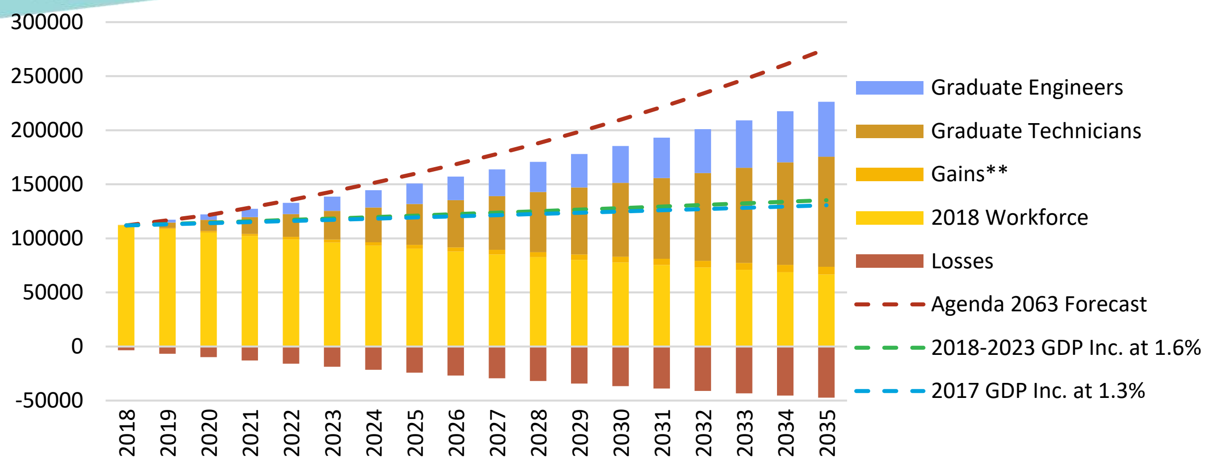


Figure 16: Flow of engineering skills based on a 2% increase in graduation rate per year

***Excludes international engineering practitioners in the country on short-term contracts*

maintenance, there will be a need for more qualified and well-experienced engineers, engineering technologists and technicians if the rate of investment and development is to increase as planned.

Allowing for foreign graduates returning to their home countries, and returning South Africans who studied abroad returning, it is assumed that 2 600 engineers and 5 200 technicians were ready to enter the workforce.*[1]

Figure 16 shows the current workforce, the losses that will occur over the 18-year period to 2035 due to retirement, mobility and mortality, and the growth in engineering capacity if local engineering graduations increase at 2% per year over the period.

The blue dotted line shows the growth in skills that would be required at the 2017 GDP growth rate of 1.3% and the green dotted line shows the growth based on the 2018–2023 GDP projection of 1.6%. A 70% employment elasticity factor has been used to extrapolate the employment demand.*[2]

It will be seen that if South Africa carries on at the low growth levels experienced in the past and projected for the next few years, there will be an oversupply of graduates, who will not be able to find employment opportunities. This was already the case at the end of 2017 when final-year classes were surveyed to determine who had found work in October of their final year. Only 30% of engineers due to complete their studies a month later and 18% of technicians had secured employment at that stage.

Only by growing at the 8% suggested by Agenda 2063 will all graduates be absorbed and a shortfall may be felt from 2024 onwards. Given the complaints about quality of graduates from some institutions and the low throughput rate, consideration needs to be given to reducing class sizes and offering quality education to ensure that graduates can eventually play a meaningful role in industry.

The increased number graduating can only be absorbed if the government reprioritises its budgets and invests in infrastructure development and maintenance, and the private sector is able to attract investment and expand to achieve the industrialisation targets.

It is also critical that rigorous graduate training programmes are developed and funded for all disciplines and sectors. At present only civil and electrical engineering graduates are being offered workplace training in local government, which is not an ideal environment for training, given the lack of capacity and the fact that most work is outsourced.

The Construction and Mining Charters recognise investment in graduate training under the Human Resource Development targets, and candidate training is recognised as a learning pathway in the SETA landscape, hence all companies should invest or access SETA funds to put rigorous graduate training in place in all disciplines.

*[1] It should be noted that graduate technologists are not counted in those entering the workforce as they are already qualified and are employed as technicians, while completing their BTech studies part-time.

*[2] Employment elasticity is a measure of the percentage change in employment associated with a 1% change in economic growth. If the growth is likely to be in agriculture, the percentage could be lower, as growth in that sector generally has to do with productivity gains and not employment, while if the growth is likely to be in high-tech manufacturing, the elasticity factor maybe more than 100%.

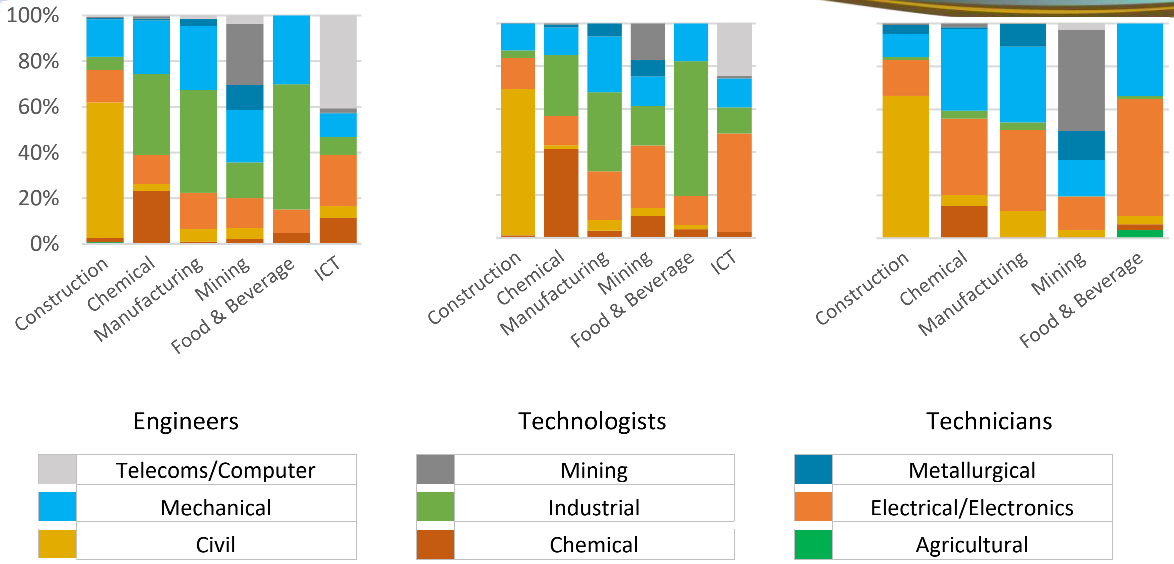


Figure 17: Discipline distribution per sector

THE USE OF ENGINEERING DISCIPLINES

To determine what training is required per discipline and in what category per sector, results from workplace skills plans submitted to the SETAs, shown in Figure 17, will be considered.

In construction, the need for civil engineering skills is to be expected, but electrical and mechanical engineering skills are also needed for electrical and fire services, heating, ventilation, air-conditioning and fleet management, among others. In the chemical, mining, food and beverage, and manufacturing processing environments, chemical, mechanical and mining engineers are to be seen in their respective sectors, supported by electrical and industrial engineers. Civil engineering staff are required across the board to handle the construction and maintenance of civil engineering infrastructure in each plant. Metallurgical engineers are seen in several sectors. ICT uses an interesting mix of electrical, electronics, industrial and telecommunication skills.

The profiles for engineers and technologists are similar, but quite different for technicians. Technicians are seen in larger numbers in applied disciplines – civil, electrical and mechanical (and mining in that sector). Their role is to ensure that processes are managed. Across the board, industries advised that technicians were inadequately trained to manage the processes in their discipline. In civil engineering, this would be construction management, or managing operations and maintenance of civil engineering infrastructure. In electrical engineering, roles would be overseeing construction, installation and commissioning, operations and maintenance or processes. In mechanical engineering, responsibilities could include overseeing the fabrication process, production or operations and maintenance. It would seem that higher education qualifications do not adequately cover these processes. The construction sector advises that civil engineering technicians need a further 42 weeks of formal training before they are able to play a role on site. The often inadequate experience gained during Work Integrated Learning does little to contribute to work readiness.

The question that needs to be asked is whether or not technician qualifications need to be refocused on the roles that technicians are expected to play in the workplace, rather than being generic qualifications. This is particularly pertinent with the introduction of the new BEngTech for technologists. In the past, technicians completed a general national diploma qualification per discipline. Those wishing to progress to technologists selected the fields in which they wished to specialise and completed a further year of theoretical training in their chosen subjects. The new BEngTech is now a stand-alone qualification which technologists will select from the outset. It could thus be time to return to the more applied role that technicians played in the past, and to structure training along the lines adopted by the French and Portuguese speaking countries in the region.

KEY RECOMMENDATIONS

To develop a sound pool of engineering professionals, able to contribute to the well-being of South Africa, the following should be considered:

Schooling

- **Mathematics and science:** Strengthen the teaching of mathematics and science to increase the number completing secondary education with acceptable results.
- **Career guidance:** Expand career guidance to attract high-calibre entrants into the engineering profession, incorporating programmes to reach female learners, and rural and low-income areas.
- **Bursaries**: Provide bursaries to attract those who excel in mathematics and science to study engineering.

Tertiary education

- **Consolidation:** Reduce the student intake, and select high-calibre students who satisfy the entrance criteria.
- **Industry liaison:** Liaise with industry on a regular basis to ensure that curricula, methods, software and equipment are relevant and up to date.
- **Technicians:** Research and debate industry requirements for the training of technicians.
- **Curricula:** Provide funding to research, modernise or develop curricula and material where required.
- **Facilities:** Raise funding to upgrade lecture theatres, libraries and laboratory facilities where required.
- **Resources:** Raise funding for computers, engineering software, access to online reference material, and laboratory and other equipment, and ensure adequate support to offer technology-relevant training.
- **Attract and retain academics:** Improve conditions of service, support and packages to attract, retain and appoint additional academics.
- **Academic development:** Provide funding for lecturer post-graduate development and facilitate opportunities for academics to gain experience in industry.
- **Teaching methods:** Apply the latest methods and technology for teaching, and train academics in 21st century approaches to teaching.
- **Student support:** Increase support to students in the form of tutoring, winter and summer schools, etc.
- **Student accommodation:** Address student accommodation.

Graduate training

- **Training standard:** Make the cidb training standard mandatory to ensure that graduates are trained on all public sector projects.
- **Training guidelines:** Develop training guidelines considering the needs of each sector and associated discipline and encourage VAs to advise on and support mentoring programmes.
- **Funding:** SETAs to support and advertise the availability of funding for candidate development.
- **Public sector support:** Ensure that public sector structures take on and train graduates and that they are absorbed and developed through the ranks.
- **Institutional support:** Institutionalise graduate training in all organisations by setting KPIs for experienced staff to act as supervisors and mentors.

Registration of engineering professionals

- **Accreditation and registration**: ECSA to ensure that accreditation and registration processes continue to satisfy the requirements of the IEA, and to support SADC countries in their endeavours to develop towards IEA recognition.
- **Identification of engineering work:** revisit the definition of engineering work, considering the definitions adopted by other SADC registering bodies to ensure alignment and mobility of professionals throughout the region.
- **VAs:** Harness the voluntary associations to assist with accreditation and registration assessments and the delivery of CPD.

Continuing development

- **CPD:** Support the participation of engineering practitioners in CPD activities.
- **Validation:** Validate short courses and skills programmes for a specified period only to ensure that training remains up to date and relevant.
- **Post-graduate studies:** Provide post-graduate bursaries to develop specialists.

- **Develop managers and leaders:** Encourage industry to continue investing in graduates after professional registration to grow management and leadership capabilities.

Public sector

- **Economic infrastructure:** Invest in the development of economic infrastructure such as electricity, roads, rail, ports and airports, and address the supply of water services.
- **Maintenance:** Invest in maintenance to preserve new infrastructure and prevent further deterioration of existing infrastructure.
- **Tariffs and payment:** Review and increase tariffs where appropriate, enhance domestic revenue collection and demand management to fund development.
- **Technical capacity:** Reprioritise budgets to fill vacant posts and build technical capacity, ensure that salaries are competitive and develop succession plans to make the public sector an employer of choice.
  - Review the OSD conditions to allow juniors to be appointed into structures from the outset and develop their careers in the public sector.
  - Approve and implement the Competency Framework developed for local government.
  - Invest in and rebuild agricultural engineering and extension support.
- **Technical decision-makers:** Ensure that engineering professionals are employed in senior decision-making posts.

Industry-wide collaboration

- **Advisory team:** Set up an engineering advisory team, recognised by government, to advise on and endorse infrastructure development proposals, tertiary curricula and graduate training programmes.
- **Collaboration:** Encourage all professional bodies to work together to share knowledge, exchange best practice and ensure coordinated planning of industry support initiatives.

ACKNOWLEDGEMENTS

So many people have contributed data, mounted research campaigns and hosted workshops, it would be impossible to list all the individual names. Thank you to all sectors that participated with particular thanks to the voluntary associations, ECSA, the Manufacturing Circle and industry organisations within manufacturing, the Minerals Council South Africa and many in government departments and parastatals who made documents and data available.

SOURCES OF INFORMATION

Data and information were gathered during meetings, interviews, workshops and via email. Surveys were carried out in several sectors. SADC reports, master plans and strategies as listed under *Plans and Strategies,* and many standard international sets of data as listed in Chapter 5, *Research Approach,* were also consulted. Further information was gathered from *Engineering News* and other news articles, Annual Reports, SETA Sector Skills Plans, InvestSA, Brand South Africa, Who Owns Whom, the Quarterly Labour Force Surveys, Statistics South Africa and from the South Africa Yearbook. Comprehensive documents focusing on specific issues in South Africa as listed below were further sources of information.

Baiphethi, M.N. and Jacobs, P.T. 2009. The contribution of subsistence farming to food security in South Africa. *Agrekon*, 48(4): 184–199.

Bhorat, H. and Rooney, C. 2017. *State of manufacturing In South Africa*. Development. Policy Research Unit Working Paper 201702, University of Cape Town.

CESA (Consulting Engineers South Africa). 2017. *Bi-Annual Economic and Capacity Survey. January – June 2017.* Pretoria: CESA.

Dednam, C. and Venter, J. 2016. *The health and growth potential of the steel manufacturing industries in South Africa*. Committee of Secondary Manufacturers (COSM).

DHET (Department of Higher Education and Training). 2014. *Skills for and through SIPs.* Pretoria: DHET.

Gumbo, T. and Onatu, G. 2015. Interrogating South Africa's people's housing process: Towards comprehensive collaborative and empowering aided self-help housing approaches. Journal of the Korean Housing Association, 26(6): 27−34.

Hara, M. , Greenberg, S., Thow, A-M., Chimatiro, S. And du Toit, A. 2017 *Trade and investment in fish and fish products between South Africa and the rest of SADC: Implications for food and nutrition se*curity. Institute FOR Poverty, Land And Agrarian Studies (PLAAS) Working Paper 47, University of the Western Cape.

Lawless, A. 2005. *Numbers and needs*. Midrand: SAICE (South African Institution of Civil Engineering).

Lawless, A. 2007. *Numbers and needs in local government*. Midrand: SAICE.

Lawless, A. 2016. *Numbers and needs in local government – update 2015*. Durban: Institute of Municipal Engineering of Southern Africa (IMIESA).

Manufacturing Circle. 2017. *Map to a million*. Johannesburg: Manufacturing Circle.

Ngozwana, S. 2015. *Bridging the skills gap for the pharmaceutical industry in South* Africa. Report for the International Conference on Harmonisation of Technical Requirements for Registration of Pharmaceuticals for Human Use.

O'Mahony, P. and Ortlepp, D. 2017. *Beyond the beverage – Drinking occasions boost beverage innovations.* Johannesburg: Glanbia Nutritionals.

Pienaar, P.L. 2013. Typology of smallholder farming in South Africa's former homelands: Towards an appropriate classification system. Master's Dissertation, Stellenbosch University.

SAICE. 2017. *SAICE 2017 Infrastructure report card for South Africa*. Midrand: SAICE.

SAICE. 2018. *Practical guide to minimum standards for civil engineering tertiary education*. Midrand: SAICE.

Transnet. 2017. *Connecting communities through port and rail planning*. Paper presented at the FIDIC GAMA Conference on Infrastructure, 7–10 May 2017, Cape Town.

WWF (World Wildlife Fund). ND. *Agriculture: Facts and trends*. South Africa. Johannesburg: WWF-SA

TANZANIA

TANZANIA, officially the United Republic of Tanzania, is situated on the east coast of Africa and includes three islands, Mafia, Pemba and Unguja, the latter two making up Zanzibar. The Indian Ocean coastline extends 1 424 km and the country is bordered by Kenya and Uganda to the north, Rwanda, Burundi and the Democratic Republic of the Congo (DRC) to the west; and Zambia, Malawi and Mozambique to the south.

Tanzania is a low-income country, which in 2017 had the tenth-largest economy in Africa. The economy is heavily based on agriculture, which is largely subsistence, contributing over 30% of the GDP and employing 67% of the labour force. Its mining sector is focused on gold and ranks as Africa's third-largest producer of gold after South Africa and Ghana. It is the only producer of tanzanite in the world.

In 2017, an estimated 2.9% of the population was infected with HIV/AIDS, placing a substantial burden on the economy. Poverty levels present a further challenge. According to the World Bank, an estimated 49.1% of the population live below the international poverty line.

The capital city is Dodoma, while Dar es Salaam, the country's most populous city, is the commercial capital and Africa's fastest-growing city.

Tanzania has experienced a rapid rate of urbanisation. Past policies made migration to the cities difficult. After a change of government, migration was allowed, but cities were not prepared for the influx. In 2016, 32% of Tanzania's total population lived in urban areas and cities. Half of the population is expected to live in major and secondary cities by 2030.

Rapid urbanisation has strained the capacity of the cities to provide the necessary infrastructure and services, which has contributed to the creation of informal and illegal settlements. These are estimated to make up 70% of the majority of urban areas.

THE ECONOMY

The economy has recorded an annual average growth rate of more than 6% over the past decade and the drive to improve public sector efficiency and crack down on corruption, led by President Magufuli, is expected to support its continued growth.

The need to invest in education, skills transfer and infrastructure to drive growth is recognised. Engineering skills will be required to meet many of the objectives.

Tanzania's inclusion as a beneficiary under the African Growth and Opportunity Act (AGOA) has allowed products to enter the USA market duty-free. The national AGOA strategy focuses on four sectors: garments and textiles; agro-processing; leather goods and footwear; and handicrafts.

PLANS AND STRATEGIES

To address development, several important plans and policies have been drawn up including:

- **Tanzanian Development Vision (TDV) 2025** which aims to ensure that by 2025 the country

Table 1: Tanzanian metrics

Population	
Total	52 555 000
Urban	31.6%
Rural	68.4%
Poverty, HIV, Unemployment	
Below international poverty line	49.1%
HIV-positive	2.9%
Unemployment	10.3%
Human Development Index	0.521
Electricity	
Production kWh	6.7bn
Consumption kWh	5.68bn
Airports and Ports	
Airports	166
- Paved	10
- Unpaved	156
Ports (coastal and lake ports)	30
Kilometres of Services	
Roads	145 204
- Paved	11 202
- Unpaved	134 002
Rail	4 567
Pipelines	1210
- Gas	311
- Oil	891
- Refined products	8
Africa Infrastructure Development Index	12.54
Access to Services	
Access to safe drinking water	55%
- Urban	89%
- Rural	46%
Access to improved sanitation	14%
- Urban	34%
- Rural	8%
Access to electricity	24%
- Urban	71%
- Rural	4%
Telephones	127 094
Mobile phones	40 044 186
Internet users	13%

would have attained middle-income status characterised by high levels of industrialisation, competitiveness, quality livelihood, rule of law and having an educated and pro-learning society.

- **Five Year Development Plan (FYDP) (2016/2017–2020/2021)** which will focus primarily on developing the employment and revenue-generating industrial sector, especially natural gas-based/fuelled industries, agro-processing industries and medium-technology industries – the need for increased energy supplies to support this growth is recognised.
- **Power System Master Plan (PSMP) (2016–2040)** which aims to boost power-generation capacity to 10 000 MW over the next decade from around 1 500 MW.
- **Sustainable Industrial Development Policy (SIDP) (2020)** which seeks to facilitate shifting the economy's engine of growth from the public to the private sector.
- **Water Sector Development Programme (WSDP) Phase II (2014/2015–2018/2019)** which will address improved water resources management, increased delivery of both rural and urban water supply and sanitation, and institutional development and capacity building.
- **Transport Sector Investment Programme (TSIP) (2018–22)** which will focus on the development and rehabilitation of roads, rail, ports, inland waterways and airports to contribute towards growth and poverty reduction.
- **Agricultural Sector Development Strategy (ASDS) II (2015/2016–2024/2025)** which aims to transform the agricultural sector into a modern, commercial, highly productive, resilient, competitive sector that will lead to achieving food security and poverty reduction.
- **National Skills Development Strategy (NSDS) (2017/17-2025/26)** which aims to ensure faster and sustained growth of medium- and high-skilled workers.

ENGINEERING ACTIVITIES

Figure 1 shows the contribution of engineering-related economic activities to the country's GDP. The largest sector is agriculture, followed by construction. Considering each in turn will give a picture of the activities, trends, challenges and opportunities for the engineering profession to contribute to Tanzania's growth.

AGRICULTURE

The agricultural sector consists of four subsectors, namely crops, livestock, forestry, and hunting and fishing. Over the past decade, Tanzania's agricultural sector has contributed about 31% of the GDP and accounts for around 67% of employment. Staple foods include maize, rice, bananas and cassava. Six key cash crops are tobacco, cashew nuts, coffee, tea, cloves and cotton.

Tanzania is endowed with huge tracts of fertile arable land and plenty of water. However, only 24% out of about 44 million ha of the total land area that is suitable for agriculture is utilised. Although irrigation holds the key to improving food security and increasing productivity and incomes, only 461 326 ha of the 29.4 million ha of irrigable land is irrigated. Of the total irrigable land, 2.3 million ha is considered to have high, 4.8 medium and 22.3 low irrigation development potential.

Usage of agricultural inputs and technology is low. Excessive reliance on rainfed agriculture, insufficient agricultural extension services, low labour productivity and deficient transportation are major constraints impeding the growth of the sector.

Post-harvest losses are particularly high due to insect infestations, inadequate storage and packing facilities, poor access to markets and infrastructure constraints. The downgrading of quality results in huge market price discounting.

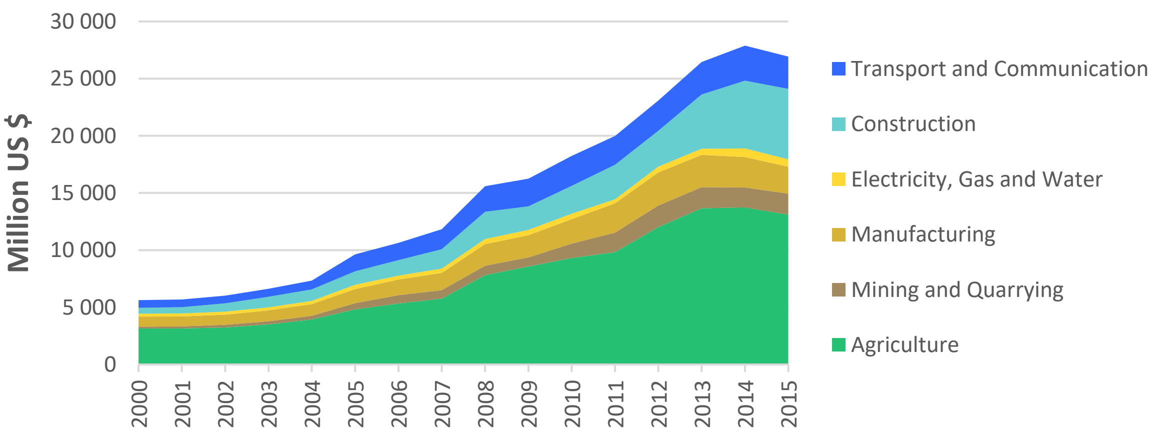


Figure 1: GPD per engineering-related economic activity (64% of the GDP)

TANZANIA

Subsistence farming

The majority of farmers are smallholders who cultivate average farm sizes of between 0.9 ha and 3.0 ha using traditional cultivation methods such as hand hoes. Only 10 % of the arable land is ploughed by tractor and production is determined by rainfall. Both crops and livestock are adversely affected by periodic droughts. The ASDS aims to support smallholders to improve productivity and market their excess produce.

Commercial farming

Many commercial farms were nationalised during Tanzania's socialist period before being privatised again in the mid-1990s. Where investors took up the opportunity, they have transformed large farms by introducing irrigation and using no-till methods, modern equipment and machinery, improved seeds, fertilisers and pesticides.

In developing the Southern Agricultural Growth Corridor, the government has earmarked nearly a third of the country for commercial farming projects, setting aside thousands of hectares of the most fertile land for private investors. The initiative hinges on irrigation. The National Irrigation Commission (NIC) has been set up to coordinate, promote and regulate the development of the irrigation and plans to expand the area under irrigation from 461 326 ha in 2015 to one million hectares by 2020/2021.

The important clusters for development are sugarcane cultivation, fisheries, forestry, and fruit, vegetable and cashew nut processing. Initial projects include fast-tracking 25 commercial farms for rice and sugarcane production to address food security and end the sugar deficit of about 200 000 tons per year. The government also aims to position the country as a regional exporter of agricultural products.

Forestry

Tanzania is home to one of the largest tree covers in the world, but it is at risk as wood remains the main source of fuel, even in urban areas. Forests are in the hands of villages, government, local government and the private sector. By 2025 Tanzania's demand for industrial wood will be around 3.7 million m^3, but existing plantations will only be able to supply about 1.1 million m^3, requiring new forest resources to be created in order not to compound the existing pressure on indigenous forests.

Fisheries

Fisheries can be divided into marine and inland fisheries, aquaculture and fish processing. The scale of operations ranges from small-scale subsistence fishing to industrial fish processing. There is inadequate infrastructure to handle the day's catch properly.

The fisheries industry requires engineering input for the manufacturing of fishing gear and accessories and for the construction of dry docking, as currently dry docking for most Tanzanian fishing and merchant ships is done in Mombasa, Kenya. The construction of infrastructure for prawn/shrimp farming, mud-crab farming, pearl culture, finfish culture, seaweed farming and hatcheries for fingerlings production is also required to expand food production.

MINING AND QUARRYING

Tanzania's mineral sector has been broadening its base and growing, with gold, natural gas, limestone (quarried to produce cement), nickel, gemstones (particularly tanzanite and diamonds) and uranium being the major contributors. However, nearly all major developments over the past decade have been in the gold subsector, making gold the most important mineral. There are significant iron ore reserves, the largest being in Liganga. A new mine is expected to start operating by 2018–2019, with commercial production and exports expected in 2019.

Tanzania's most important diamond mine is the Williamson Mine, based on the 146 ha Mwadui kimberlite pipe. This is the world's largest economic kimberlite pipe to have seen continuous mining. Tanzania produces a variety of gemstones, including amethyst, aquamarine, garnet, ruby, sapphire, tanzanite and tourmaline. Tanzanite is found at only one location in the world, the Mererani Hills in northern Tanzania.

Coal is currently exploited on a small scale at Kiwira Coal Mine in the Mbeya Region and at the Tancoal Energy Limited Mine at Ngaka in the Ruvuma Region. The Mchuchuma Mine was expected to come on stream in 2017 and others are planned to support the development of more coal-fired power stations.

Huge deposits of uranium have been identified in recent years. A major uranium development, the Mkuju River Project, was expected to come into full production by the end of 2018.

Sadly, little value is added locally once basic refining has been performed, and the profit margins available to gold middlemen are low. A large infrastructure deficit, technological deficiencies and skills gaps are some of the challenges limiting beneficiation.

The impacts of this sector are therefore restricted to the direct earnings of those extracting minerals. By contrast, quarried limestone is locally beneficiated into cement. Based on the TDV 2025, the mining sector is expected to contribute 10% to GDP by 2025.

In early 2017 the government announced an immediate ban on the export of concentrates and ores of all metallic minerals to ensure that '…*value addition activities'*, such as smelting and refining, are undertaken locally. Although 99% of the gold mined is already processed locally, the mixed silver, copper and gold concentrate is challenging to separate, and it is not economically viable to build a smelter for this concentrate. Similarly, the volumes of copper currently being produced would not generate the necessary output for a smelter to be profitable.

Where smelting and refining are viable, the implementation of the policy did not take into account the fact that it will take at least three years to develop smelting and refining facilities, which will also require considerable financing and significant power. Ensuring reliable power from the existing grid is likely to require diverting energy from elsewhere.

The first columbite-tantalite (coltan) smelter in Africa will be built in North America and shipped to Dar es Salaam. It will have the capacity to process 3 000 tons per year of coltan concentrate. Tantalum is widely used in the manufacturing of electronics and superalloys, and niobium is used in the production of high-strength, low-alloy steels. The value of coltan can be significantly increased through smelting, separating all the minerals in the concentrate and upgrading them to oxides.

In recognition of the growing mining industry and the apparent lack of the necessary skills, the Tanzania Chamber of Minerals and Energy has adopted an Integrated Mine Technical Training Programme. The Arusha Technical College and Moshi College have been designated to offer this up-to-date training.

Deposits cannot be commercialised without transport infrastructure and sufficient power. The current transport infrastructure is suitable for the low volumes of high-value minerals, such as gold and gems, but to develop nickel or coal projects will require significant upgrades of ports, rail, roads and power supply.

MANUFACTURING

The five top manufacturing export industries are food products, rubber and plastics, tobacco products, other non-metallic mineral products and textiles, which reflects the manufacturing value add (MVA), as

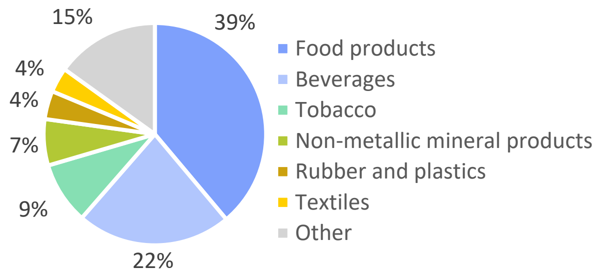


Figure 2: Percentage manufacturing value add per subsector, 2013

(UNIDO, Mapping Industrial Production in Tanzania)

shown in Figure 2. Beverage exports are limited, as the focus is almost completely on the domestic market.

In 2013, it was estimated that there were 48 474 manufacturing companies employing 231 098 people, but only 998 of these companies employed more than 10 people.

Inadequate infrastructure, including the poor road network, uncompetitive rail services, unreliable energy and outdated machines and equipment limit the development of manufacturing value chains. Inadequate technical skills and lack of access to sophisticated information and communication technology are further challenges.

The current industrial policy is directed towards deepening private sector-led industrial growth as a way of transforming the economy from its heavy reliance on agriculture to becoming a semi-industrialised country, with manufacturing contributing at least 40% to the GDP by 2025.

Food, beverages and tobacco products

Sugar, rice, tea, coffee and oilseed processing are notable secondary industries, with several sugar and rice mills, 20 tea factories, 15 curing and hulling coffee plants and 26 oilseed plants producing for local and export markets. Grains, dairy, confectionery and many other food products are also manufactured locally. Fish processing is important, with more than 30 processing factories, mainly around Lake Victoria, producing frozen and chilled Nile perch fillets for export.

The beverage sector consists of the distilling and blending of spirits and the brewing of wines, cider and beer. Tanzania Breweries Ltd (TBL), the largest brewing company in the country, is developing a new brewery for completion in 2020 which will produce 1 million hectolitres of beer per year once in full production. The soft drinks subsector comprises the processing and bottling of juices, natural spring water and mineral water, and carbonated drinks, many of which are produced locally under international licence agreements.

There are three major buyers in the tobacco market: Tanzania Leaf Tobacco Company (TLTC), Alliance One Tanzania Ltd (AOTTL) and Premium Active Tanzania Ltd (PATL). The first two have their own processing facilities, while Premium Active processes its tobacco using the facilities of its two competitors. Processing and packing of tobacco is done according to the customer's (i.e. the cigarette manufacturer's) specifications. The specifications indicate the preferred processing operations, quality control test requirements, packing moisture, packing weights and packing materials. The tobacco-processing facilities can handle tipping and threshing, loose leaf packing, butted loose leaf and bundles, and hand strips packing. An additional tobacco-processing facility was opened in March 2018 in Morogoro.

Textiles, clothing and leather

Cotton is Tanzania's largest export crop after coffee. Although Tanzania is a major cotton producer, the textiles and apparel sector is small. Tanzania processes only about 20% of its own cotton after ginning, and it exports the rest. There are about 35 cotton ginneries, all processing cotton lint for the export market. Some ginneries process cottonseed into cottonseed oil and seed cake.

Tanzania's textile producers consume in the region of 30 000 metric tons of cotton lint per year (2012). Most of the lint is spun into 100% cotton yarns, which are made into traditional lightweight woven fabrics (*khanga* and *kitenge*). Tanzania is among Africa’s top five producers of conventional (i.e. non-organic) cotton and it is the world's fourth-largest producer of organic cotton (after India, Turkey and Syria). However, the supply of cotton lint and yarn to local textile producers is very limited. Most textile producers do not produce year-round due to shortages of raw materials.

Technical challenges such as unreliable power supply, old machines and equipment, lack of information and communication technology and high transportation costs are barriers to increased production.

Tanzania has the third-largest livestock population in Africa, but its production of leather and leather products is very limited. About three-quarters of locally produced raw hides and skins are exported and 95% of the remainder is exported after limited processing.

Timber, pulp, paper and packaging

Forestry-related establishments include sawmills, impregnation plants and paper mills. Products include sawn timber, utility poles, construction materials, furniture, charcoal and a range of papers. Apart from two sawmills that use advanced laser technology and hewsaws, most mills use inefficient and old technologies, with small-scale sawmills being particularly wasteful.

Annual charcoal consumption is estimated at about one million tons per year. Over 70% of households in urban Tanzania use charcoal as their main source of cooking energy. The government is considering gas as an alternative energy source for cooking.

Plastics, chemicals and other non-metallic mineral products

The plastics industry produces a range of products: household plastic goods, furniture and footwear; injection, blow moulding and film extrusion products; tubing, moulds and packaging, including PET bottles; and PVC and polyethylene pipes. It is the largest manufacturer of PVC water reticulation, drainage piping systems and fittings in East and Central Africa.

With regard to chemicals, there are a few local producers of skin care, hair care and baby care products, but the cosmetics and beauty sector relies largely on overseas imports and cross-border trade from Kenya. Most imports are counterfeit products from China which do not conform to the standards of the Tanzania Food and Drugs Authority (TDFA). Other chemical manufacturing activities include the production of detergents for commercial and household use.

Paints, additives and other speciality chemical products are also produced. Rubber products include tyres, tubes, conveyor and fan belts, rubber mats, gloves and footwear.

Tanzania currently imports most of its fertilisers. However, a US$3 billion fertiliser factory is being constructed which will become Africa’s biggest fertiliser producer. It will use hydrocarbons from offshore gas to produce ammonia, which is a key ingredient in fertilisers. The government is in the final stages of creating a specialised industrial zone for petrochemical industries in the region of Mtwara to attract investments and form a chemical industrial cluster.

There are seven cement manufacturers in Tanzania which produce pozzolana and Portland limestone cement and a range of cement products. The production capacity increased from 3 million tons in 2013 to 9 million tons in 2017.

Several large and medium-sized firms are active in the production of glass, mostly producing containers and building materials. Glass production has been increasing steadily since 2005, partly because of growth in the construction sector and a shift in favour of glass for interior walls and partitions.

Pharmaceuticals

Local manufacturers are concerned mainly with the production of over-the-counter medicines and generic antimalarials, antiretrovirals and antibiotics. Production has been in decline since 2009, and in 2016 only five manufacturers remained. The increasing costs of raw materials, due to the slide in the exchange rate, and the lack of technical skills are cited as the main challenges.

Computer, electronic and optical products, and electrical equipment

Electrical control and security devices, switchboard apparatus, radios and other electronic devices are manufactured, but most high-tech electronic and medical equipment, and industrial systems are imported. Engineering skills are, however, required to assist with selecting the appropriate solutions, installation, calibration and ongoing maintenance.

Metal industries, machinery and equipment

There are many steel mills that manufacture steel and/or aluminium products, including drawn wire, rebars, pipes, sections, sheeting, plate, etc. for the construction and other sectors.

Electrical motors, transformers and transport equipment are also manufactured. Bicycles, carts and vehicle bodies are built, and spare parts are manufactured. However, the country is fully reliant on imported automotive products such as passenger cars and heavy equipment/machinery.

ELECTRICITY, GAS AND WATER

Electricity

In 2013, only 24% of the population had access to electricity, made up of 71% of the urban population and a low 4% of the rural population.

In 2016, Tanzania's total installed power capacity was 1 358 MW. Tanzania also imports power from Uganda, Zambia and Kenya. TANESCO, a government utility, responsible for the generation, transmission and distribution of electricity produces 98% of the electricity.

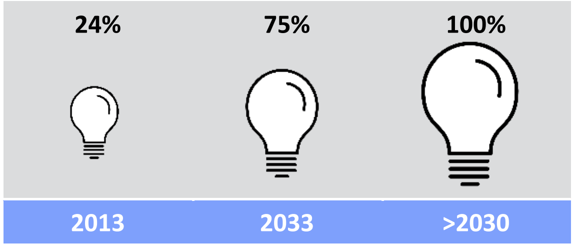


Figure 3: Target dates for access to electricity

With 42% depending on hydropower, as shown in Table 2, droughts, which are becoming increasingly severe, have resulted in power supply shortages.

Table 2: Sources for power generation

INSTALLED POWER 2016	% OF SUPPLY
Hydro	42%
Natural gas	45%
Liquid fuel	13%

There are plans to increase generation capacity to 10 000 MW by 2025. To achieve this, the government has embarked on reforming the Electricity Supply Industry (ESI) by attracting private capital. In line with the master plan, electricity connection should increase to 50% by 2025, and to 75% by 2033. To increase generation from the many sources available Tanzania plans to:

- Expand hydropower capacity from 562 MW taking advantage of the country's vast water resources which are said to offer the potential of an additional 4 GW.
- Tap into the recent discoveries of natural gas reserves off the coast, which are said to be large enough to cover the domestic power requirements and make Tanzania the next natural gas hub in Africa. The first developments will deliver 2 000 MW of gas-fired electricity by 2018.
- Develop the extensive coal reserves to generate capacity of 400 MW from the Kiwira Coal Mine and 600 MW from the Mchuchuma and Katewaka Coal Mines.
- Harness renewable energy sources such as hydro, solar, wind and biomass technologies. The first major project is being funded by the World Bank and should be complete by 2023.

To address rural electrification, the Rural Energy Agency (REA) was set up, governed by the Rural Energy Board (REB). The Rural Energy Fund (REF) has been set up under the Agency to raise and manage funds for development. The goal is to electrify all villages by 2021 at a rate of 2 000 villages per year. So far, more than 5 000 villages out of 15 290 have been electrified, mainly through national grid extensions. In remote areas mini-grid development and stand-alone solutions, for example solar home systems, will be implemented. An action plan to ensure increased use of improved solutions for cooking has been developed.

Oil and gas

Tanzania has potential natural gas reserves of up to 441 trillion ft^3 solely in the coastal region which will be harnessed for power generation. In 2013, 14 exploration companies were active. Two exploration wells have encountered commercial quantities of natural gas. Kiliwani North-1 tested gas at 40 million cubic feet/day (approximately 115 million litres per day) and is being developed for commercial production.

Tanzania is a net importer of petroleum products, with supply being conducted through a Bulk Procurement System (BPS). In 2015, 2.99 billion litres were supplied to the local market and 1.61 billion litres were exported to landlocked neighbours, including Zambia, the DRC, Rwanda, Malawi and Burundi.

A heavy oil refinery constructed in 2016 will produce approximately 27 000 tons of oil and 10 000 tons of lubricant annually, saving the country from having to import these products, as had been the case in the past. Part of the production will be exported to neighbouring countries.

Water and sanitation

In 2015, some 55% of the population had access to safe drinking water, made up of 89% of the urban population and 46% of the rural population.

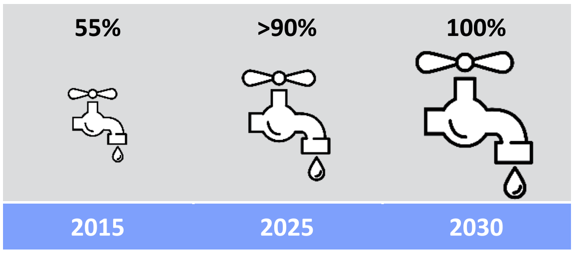


Figure 4: Target dates for access to safe drinking water

The same is not true of sanitation, where only 14% of the population had access to improved sanitation, made up of 34% of the urban population and 8% of the rural population. The TDV 2025 plans for all urban areas and 90% of rural areas to have access to safe drinking water by 2025.

Tanzania is blessed with vast water resources, including lakes such as Lakes Victoria, Tanganyika, Nyasa, Rukwa, Manyara, Eyasi and Natroni, as well as rivers and basins across the country. However, with the fast-growing population, climate change and extensive use of water for agriculture, which is above the world average, it is predicted that the country will be water stressed by 2025. This will require significantly improved agricultural practices and water resource management.

The water sector is divided into two subsectors, namely water resources and sanitation. The provision of water supply and sanitation services is carried out by some 20 Water Supply and Sanitation Authorities, which are responsible for the management of services mostly in urban areas, and about 100 Community-Owned Water Supply Organisations in rural areas.

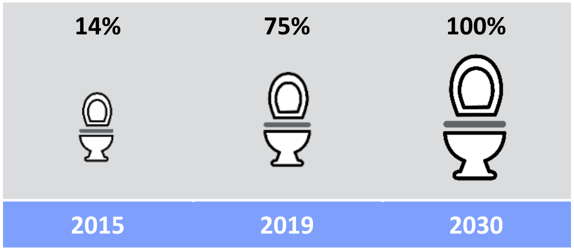


Figure 5: Target dates for access to improved sanitation

The Dar es Salaam Water and Sewerage Authority (DAWASA) and the Dar es Salaam Water and Sewerage Corporation (DAWASCO) are responsible for the provision of water supply services in Dar es Salaam and the neighbouring areas of Kibaha and Bagamoyo. Many of these structures are under-resourced, resulting in limited maintenance. Non-revenue water losses are as high as 53% and the water quality standards do not comply with prescribed government standards in many areas. Servicing of the expansive informal settlements has been limited, presenting significant health risks.

Ambitious targets have been set to increase access to safe drinking water and improved sanitation, as shown in Figures 5 and 6. These will require significant funding, but more importantly, a dramatic increase in engineering skills. Some of the KPIs listed in the water sector development programme include:

- Rehabilitation of 20 medium-sized dams and 19 889 non-functioning water points, and the construction of three major dams and 59 treatment plants by 2019.
- Recruitment of 1 000 staff in various technical disciplines (hydrologists, hydrogeologists, environmental engineers, water resources engineers, economists, community development

officers, chemists, etc.) in the Ministry of Water, Basin Water Boards and Laboratories.
- Deployment of 386 engineers and 3 338 technicians to Local Government Authorities.

TRANSPORT AND COMMUNICATION

Tanzania has three main regional transport corridors, the Northern, Central and Southern Corridors. In the **Northern Corridor**, most freight is transported by road, although, given the distances, it could be more cost-efficient to use rail. Dar es Salaam is a key port for the landlocked countries served by the **Central Corridor**. The corridor connects the port by road, rail and inland waterways to Burundi, Rwanda, Uganda, the eastern part of the DRC and central and northern-western Tanzania itself. The **Southern Corridor** provides road and rail access to the northern and central provinces of Zambia, Malawi and the Katanga province in the DRC.

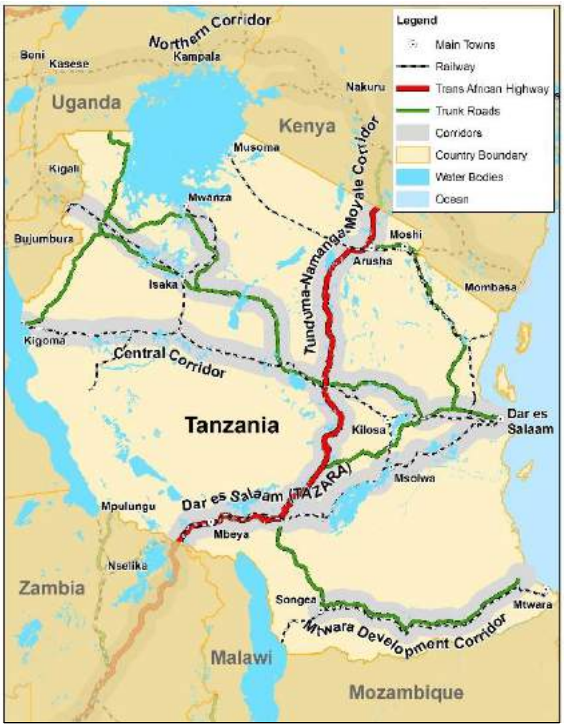
Roads

Road transport is the most widely used form of transport, carrying over 90% of the passengers and 75% of the freight. The road network is approximately 145 204 km long.

The trunk and regional road network consists of approximately 35 734 km, of which approximately 9 719 km are paved. Seventy per cent of the trunk and regional roads are in good condition, while the remainder vary from fair to poor condition.

The trunk and regional roads are managed and maintained by the Tanzania National Roads Agency (TANROADS), which falls under the Department of Works in the Ministry of Works, Transport and Communications. Roads are planned by the Department. Many are designed by the in-house Tanzania Engineering Consulting Unit (TECU) but they are prioritised and developed by TANROADS. The unit is a good training ground for young graduates to learn how to design roads and associated infrastructure.

The district, urban and feeder roads used to be the responsibility of local government under the oversight of the Prime Minister's Office of Regional Administration and Local Government. However, in 2017, responsibility for the road network was moved into a separate agency, the Tanzania Rural and Urban Roads Agency (TARURA). Freed of political interference from the local government sector, the team of road engineers transferred to the Agency have been given the task of optimising the use of funds available for the development of rural and urban roads.



Disclaimer:
Aurecon gives no warranty of any kind, expressed or implied, with regard to the map or data whether for its reliability, accuracy or completeness and shall not be held liable in any event for any loss or damage in connection with or arising out of the use of this data or map. The Client accepts all inherent limitations of the maps and data, including the fact that the maps and data are dynamic and in a constant state of maintenance, correction and revision. The data and map remain the sole property of the CLIENT and may be used for purposes of this Project with the prior written approval from the CLIENT. aurecon

Figure 6: Transport corridors

All units involved in road development complain of inadequate budgets for road upgrades or maintenance. To improve traffic flows from Dar es Salaam to Chalinze, a 110 km six-lane toll road is planned for completion by 2022. Urban initiatives to improve traffic flows include the development of several flyovers in Dar es Salaam and expansion of the bus rapid transit network.

Rail

Tanzania has two railway systems of different gauges. The oldest system, owned by Tanzania Railways Limited, now Tanzania Rail Corporation (TRC), was constructed to a 1 m gauge (1 000 mm) initially between Dar es Salaam and the central and western areas of the country. A second east–west line was built from the port of Tanga to Moshi and was subsequently extended to Arusha and linked to the Kenya and Uganda rail systems. Branch lines have been added over the years. A new proposal is to add a 600 km line from Arusha to Musoma to link Uganda through the port of Musoma on Lake Victoria.

Due to the age, condition and gauge of the lines, the government has decided to upgrade the central line to standard gauge. This will largely replace the existing 1 m gauge network and extend into Rwanda (a distance of 371 km from Isaka to Rusumo and a further 521 km to Kigali) and Burundi (a distance of 200 km from Uvinza to Musongait). The contractor appointed, expects to hire 1 000 engineers to work on the project!

Tanzania also plans to construct a new standard gauge line from Mtwara to Songea and on to Mbamba Bay, with spurs to Mchuchuma and Ligaga – an overall distance of 1 000 km. This will link to the Liganga iron ore and Mchuchuma coal mining areas and open up the southern part of Tanzania, as well as serving Malawi, Mozambique, Zambia and Zimbabwe. In total, Tanzania plans to spend US$14.2 billion over the next few years to build 2 561 km of standard gauge rail lines connecting its main Indian Ocean port of Dar es Salaam to its hinterland and neighbouring states.

The Tanzania-Zambia Railway (TAZARA) is the second system constructed to the Cape gauge standard of 1 067 mm, like the rail systems of southern Africa to which it links. The line is 1 860 km long, of which 975 km is in Tanzania and 885 km in Zambia. An interchange was constructed between this railway and the TRC system at Kidatu to facilitate movement of freight between the two rail systems. The railway is jointly owned by the governments of Tanzania and Zambia, and is managed by TAZARA.

Road freight has largely replaced rail freight. Due to the deteriorated condition of the lines and the rail service, the volume hauled by the TRC represents only 13% of the peak demand of former years and the traffic on TAZARA is only about 15% of its peak demand. Investment in infrastructure, power generation, locomotives and rolling stock is key to taking traffic off the roads and back onto rail.

Ports

Both coastal and lake ports are the responsibility of the Tanzania Ports Authority (TPA). The ports serve a large market which includes the country's hinterland and the neighbouring landlocked countries. The main seaports, Tanga in the north, Mtwara in the south and especially Dar es Salaam, provide vital access to world markets for this region. The ports on Lake Victoria, Tanganyika and Nyasa are important for local and international trade, although they now suffer competition from road transport in many locations.

With the increased volumes expected from road and rail development, there are many projects underway to improve the efficiency of Dar es Salaam Port. These include improvement of Berths 1 to 7, widening the channel entrance and increasing the draft to 15.5 m, improving the rail layout in the port, and a roll-on/roll-off (RoRo) berth. Mwanza and Kigoma ports on the lakes are also being upgraded. The major port upgrades are listed in Table 3.

Airports

The country has 368 airports, with the Tanzania Airports Authority (TAA) being responsible for 58 airports on the mainland. Most of the airports are private airfields owned by mining companies and tour operators.

The TSIP has earmarked development of the Julius Nyerere International Airport to serve as a regional passenger and cargo hub by 2020, and to grow from 3.5 million passengers to 6 million passengers.

Figure 7: Laying of Phase I from Dar es salaam to Morogoro (205km) Standard Gauge Railway (SGR)

(Courtesy: Government of the United Republic of Tanzania)

The Msalato International Airport, a new airport 14 km from Dodoma city centre, is to be constructed to accommodate the increased passenger volumes due to the relocation of the government from Dar es Salaam to Dodoma.

Resources in this sector are challenging. More aircraft are needed, as are more technicians and aircraft engineers able to keep up with the changing technology. To date, Tanzania has not offered aircraft engineering qualifications, but they were introduced by the National Institute of Transport in 2016. The first students will graduate in 2019.

Pipelines

There are three pipelines in Tanzania, all of which are to the energy sector. They are the Tanzania–Zambia Mafuta pipeline (TAZAMA) which transports crude oil from the Dar es Salaam Port to an oil refinery at Ndola in Zambia, the Songo-Songo pipeline which transfers natural gas from Songo-Songo Island to Dar es Salaam, and the Mnazi Bay pipeline which transfers natural gas from the Mnazi gasfield to a power plant in Mtwara. The oil and gas industries are currently expanding at a fast pace as new sources of supplies are being discovered.

Waterways

Inland waterways link Tanzania with neighbouring countries. Lake Victoria plays an important role, with ferries carrying rail wagons and vehicles between Uganda and Tanzania. Lake Tanganyika carries commercial traffic from the DRC, Burundi and Zambia. Tanzania's lake ports require substantial infrastructure improvements to keep up with local and regional demands. Two newly built cargo and passenger ships were recently brought into service to improve maritime transport, and a further passenger ship is being built. Upgrading the infrastructure will attract significantly more trade opportunities.

Communications

As of 2017, Tanzania had 127 094 fixed-line telephone subscriptions and 40 million mobile users, representing a 72% penetration rate, with Vodacom being the largest provider. Tanzania has two fixed-line operators (TTCL and Zantel) and seven operational mobile networks, with four major operators – Vodacom, Airtel (formerly Zain), Tigo and Zantel. Internet penetration remains low at just 13%.

The liberalisation of Voice-over-Internet Protocol (VoIP) telephony, as well as the introduction of third and fourth generation (3G, LTE) mobile services and wireless broadband networks, has boosted the internet sector which had been hampered by limited development of the traditional fixed-line network.

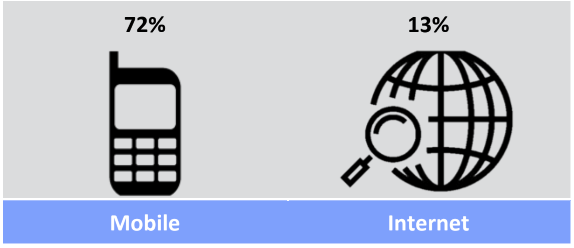


Figure 8: Percentage of population connected to services

Following the launch of mobile broadband services, the mobile network operators have become the leading internet service providers. Operators are hoping for revenue growth in the mobile data services market, given that the voice market is almost entirely prepaid and voice revenue per user continues to fall. To this end they have invested in network upgrades. A fast-developing source of revenue is from mobile money transfer and m-banking services.

Fibre optic submarine cables first landed in Tanzania in 2009 with the SEACOM cable providing a much needed boost in global connectivity, linking them to India and France. The EASSy cable landed in 2010 providing a huge boost in bandwidth availability, with a design capacity of over 10 Tbps, and a redundant connection in the event of a cable break occurring. Tanzania also hosts the landing station for the SEAS cable, which connects the Seychelles to the global network. Prior to these fibre cables, the country was entirely dependent on expensive satellite connections, which still provide the country with a backup connection to the global network.

TTCL announced in mid-2018 that it would commence a nationwide FTTH rollout to enable users to connect to high-speed fibre-optic broadband services delivered directly to their homes with connection speeds of up to 50 Mbps.

CONSTRUCTION

Construction is important in any country due to its ability to create jobs and develop skills. Many private sector developments in agriculture, mining and manufacturing have been discussed in earlier sections. However, infrastructure development by the government constitutes the largest sector of the construction industry.

In 2015, the AfDB's portfolio in Tanzania consisted of 29 projects totalling some US$1.97 billion, nearly half of which was allocated to transport infrastructure to improve the domestic and regional network. The funds also contributed to the development of affordable electricity. Additional resources have been provided from the Africa Growing Together

Fund, trust funds, renewable energy financing and co-financing with other partners.

The World Bank's portfolio in Tanzania includes 25 projects totalling nearly US$4 billion, most of which is dedicated to the Intermodal and Rail Development Project to address the movement of goods, and to promote agricultural trade and job creation across the country. In March 2015, the World Bank approved the Dar es Salaam Metropolitan Development Project to improve urban services in Dar es Salaam by upgrading and building priority roads and drainage systems. Both projects are expected to be completed by 2020. The major projects planned are listed in Table 3.

Housing

Tanzania suffers from a shortage of good-quality and affordable housing. The current demand for housing is estimated at 200 000 houses per year, with a total backlog of 3 million houses.

Many developments are being driven by the National Housing Corporation (NHC), the Tanzania Building Agency (TBA), donors and NGOs, but the pace of delivery is inadequate to address the annual demand, never mind the backlog. In addition, engineering services are needed for new housing developments, which puts a further constraint on development. A Public Servants Housing Scheme is also underway, which will construct 50 000 affordable housing units in five phases. Public housing projects have generally been in decline and the private sector and pension funds have become the primary investors, which only addresses the needs of the those who can afford to pay for housing.

LOCAL GOVERNMENT

The mainland of Tanzania is divided into 26 regions; and there are a further three on Zanzibar and two on Pemba. In total, 184 local government authorities have been created on the mainland, comprising 137 districts and 47 urban authorities. The urban authorities include cities such as Dar es Salaam, Tanga, Mbeya, Arusha and Mwanza, municipalities such as Dodoma, Iringa, Kilimanjaro, Morogoro, Shinyanga and Tabora, and town councils.

TANESCO provides electricity for all consumers and the water boards are responsible for the provision of water and sanitation services. However, engineers in local government are responsible for planning and ensuring that the services are developed, and for providing and maintaining street and traffic lights. The district and feeder roads were the responsibility

Table 3: Major projects identified, or being planned or under construction

PROJECT		VALUE US$	START YEAR	END YEAR
Energy	Liquefied Natural Gas (LNG) plant in Lindi	TBD	2022	TBD
	Crude Oil Pipeline from Uganda to Tanzania Port Tanga	$3.6bn	2017	2020
	Gas-fired power plant	$1bn	Planning	
	Ruhuhu Valley irrigation and hydropower scheme	Pre-feasibility		
	Zambia–Tanzania–Kenya Interconnector (ZTK)	$307m	2017	2021
	Songwe River Basin Development Project – dam, hydroplant, irrigation	$565m	2018	2025
Ports & airports	New Mwambani Port	$566m	Seeking PPP	
	Upgrades to Dar es Salaam Port	$421m	Ongoing	
	Port Bagamoyo and Economic Zone	$10bn	2018	TBD
	Msalato International Airport, Dodoma	$1.5bn	TBD	TDB
Roads	Upgrading of over 2 000 km of road to bitumen standard using government and external funds – seeking finance in many cases	$1.8bn	2018	TBD
	Dar es Salaam–Chalinze six-lane toll road (144 km)	$1.48bn	Seeking PPP	
Rail	Central Railway line			
	• Phase 1: Makutupora–Tabora–Isaka–Mwanza (578 km)	$3.3bn	Seeking finance	
	• Phase 2: Tabora–Kigoma (411km and Isaka–Rusumo–Kigali (521km)	TBD	Seeking finance	
	Tanga (Mwambani)–Arusha–Musoma (938 km) railway and ports	$3.43bn	Seeking PPP	
	Mtwara–Mbamba Bay–Mchuchuma–Liganga standard gauge	$3.6bn	Seeking PPP	
	Connection of the New Bagamoyo Port to the TAZARA line (150 km)	Feasibility		
	Link from TAZARA Chikola–Magamba Coal Mine (20 km)	Feasibility		
	Link from TAZARA Mlimba Station–Mchuchuma–Liganga–Mbamba Bay	Feasibility		
	Railway network for Dar es Salaam Commuter Train Services	Feasibility		
	Intermodal and rail development project	$300m	2018	2021
Other	Dar es Salaam Metropolitan Development Project	$330m	2018	2021
	Mchuchuma coal and Liganga iron ore project	$2bn	2017	2019
	Fertiliser factory, Mtwara	$3bn	2019	TBD

of local government until the role was transferred to the new agency, TARURA. TARURA is now responsible for a network of some 108 946 km, exclusive of unclassified community roads.

The network comprises almost 1 450 km of paved roads, 24 405 km of gravel roads and just over 83 091 km of earth roads, half of which are said to be in poor condition and become impassable during the rainy season. In the past, each municipality needed to plan and manage its own road development and maintenance, and appoint contractors. Now that all local government roads are consolidated into one agency, integrated planning is possible and appointing subcontractors to maintain larger areas makes maintenance management more cost-effective. The activities of TARURA are funded through the fuel levy. TARURA reports vacancy levels of around 45%.

The engineers remaining in local government are responsible for fire services, primary schools, health facilities and other amenities, municipal buildings, irrigation and agricultural schemes, and handling building control and waste management. They must also manage their fleets of vehicles.

EDUCATION, TRAINING AND PROFESSIONAL DEVELOPMENT

Education and training is a vital part of developing engineering capacity. All elements, from teaching appropriate subjects in schools to continuing professional development (CPD), need to be in place to educate and train engineering personnel and ensure that they remain abreast of the latest technology, challenges and emerging solutions.

PRIMARY AND SECONDARY EDUCATION

Primary education spans seven years, from Standard 1, known as D1, to Standard 7 or D7. To proceed to a government secondary school, learners must pass the Primary School Leaving Exam (PSLE), otherwise they can continue their education in a private school. Alternatively, learners may enter vocational training after Standard 7.

Secondary education is broken into six years, made up of four years, known as lower secondary, working towards passing the O+ national exam. Passing the O+ qualifies learners to proceed to the final two years, higher secondary, after which they take the national A+ exam. If they earn a certain grade, they may enter university directly, failing which they must complete a diploma before entering university.

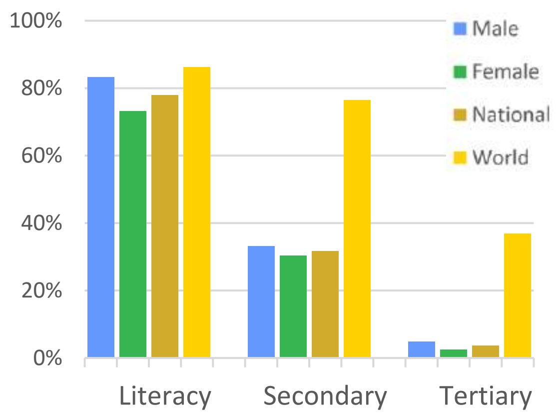


Figure 9: Literacy and enrolment statistics
(UNESCO from 2013 to 2015)

Although the percentage enrolled in primary education is high, analysis of the high drop-out rate from those starting school to entering secondary school is cause for concern. Only about 23% complete lower secondary education, only about 5% proceed to upper secondary and only about 3% complete secondary education.

The quality of education in mathematics and the sciences is a challenge, and the number of qualified teachers in these subjects has been decreasing. In the case of science, few schools have suitably equipped laboratories. English language proficiency levels are also comparatively low. These factors limit the number who can select semi-skilled or skilled careers. In 2009 it was noted that fewer than 800 school leavers attained the entry requirements for engineering degrees.

TERTIARY EDUCATION

There are some 60 universities and colleges in Tanzania, a huge increase from one university in the 1970s. Although impressive in terms of making tertiary education accessible to many more, this has come at a price of reduced quality in education due to inadequate human capital and facilities.

The number of academics with PhDs and post-doctoral studies is limited, with lectures at times being delivered by tutors. In 2009, it was estimated that the average vacancy rate in engineering faculties was around 30%. The proliferation of private universities has also affected staffing numbers, as private universities pay higher salaries and have attracted top academics away from public institutions.

Twenty or more institutions offer engineering qualifications. Engineers complete a BSc(Eng), incorporated engineers a BEng and technicians a diploma. The Engineers Registration Board (ERB) only registers engineers and incorporated engineers and not technicians. Furthermore, several institutions offering BSc(Eng) and BEng are not recognised, hence students graduating from these institutions will not be able to register professionally once they become competent practitioners. The Water Institute shown in Table 4 is one such institute which offers water and irrigation qualifications. Several others offering computer, system or software engineering are not included here, as their qualifications are considered to have inadequate engineering content.

Tertiary education has responded to the needs of industry by developing several engineering qualifications relevant to local needs such as: irrigation and water resource management; bioprocesses and post-harvest (grouped under agriculture in Table 4); maritime; oil and gas; textile engineering; and industrial and municipal engineering management. Aircraft engineering has also been added at technician and incorporated engineer level.

The data was collected from engineering departments, university registrars, the Tanzania Commission for Universities (TCU), the National Council for Technical Education (NACTE) and the Ministry of Education, Science and Technology. The dates for which data was supplied and the formats varied; in some instances, the totals were given for a year, and not the numbers per discipline. Where individual numbers were not given, but a qualification was in place, a tick is shown in Table 4. Totals, where known, are included in the summary at the bottom of the table.

The graduation trends, for only those institutions able to supply several years of historical data, are shown in Figure 10 and the split by discipline, category and gender is shown in Figure 11. This does not mean that large number of engineers are not qualifying. In Table 4 it can be seen that the numbers qualifying are quite substantial – a far cry from some 120 graduates 20 years ago. Furthermore, the data presented is for 2015. Where audited graduation data has been made available for 2016 and 2017, huge increases in graduations are evident, with one institute graduating 514 engineers in 2017 compared with 63 in 2015, another graduating 240 versus 94 and a third graduating 615 versus 176.

Similar increases in the number of technicians graduating are also evident. The number of agricultural engineers graduating from Sokoine increased from 20 in 2015 to 164 in 2016 but dropped to 70 in 2017 – still substantially higher than in former years.

With increasing numbers, the quality of graduates is considered to be a problem, partially due to limited resources as discussed above, compounded by the poor grounding at school and the low levels (or lack) of soft or behavioural skills. Industry also complains that the training of technicians has largely become theoretical training in the classroom rather than problem-based hands-on training.

Funding under the first phase of the Royal Academy's Higher Education Partnerships for sub-Saharan Africa (HEPSSA) was accessed in 2015. In response to the above findings, the UDSM elected to use the funds to set up an Innovation and Entrepreneurship Centre (UDIEC) aimed at supporting students and staff from the university, as well as other academic institutions, to become job creators rather than job seekers.

Another concern has been the trend of converting technical colleges into universities, such as the Dar es Salaam and Mbeya Technical Colleges having become an institute and a university of technology respectively. This has been driven partially by the Higher Education Students Loans Board (HESLB) which has been making funds available from the skills levy for degree studies, diverting funds that were previously focused on colleges and the training of artisans and technicians. President Magufuli has intervened and reversed this trend, as many students being accepted into higher education did not meet the entrance requirements.

Accreditation

The TCU was set up to *'…recognise, approve, register and accredit universities operating in Tanzania and local or foreign university level programmes being offered by registered higher education institutions'*. Included in their role was handling applications and placing students who wished to follow higher education studies. Universities were not at liberty to select their own students, and students often did not get the choice of course for which they applied. Since 2017, the process has been changed, and students may now apply directly to the universities of their choice.

Although the TCU accredits qualifications, the level of rigour does match that of the Washington Accord, and there are complaints that the number of unemployed graduates is on the increase as they are not equipped for the world of work from a theoretical or soft skills point of view.

Table 4: Engineering graduations in Tanzania in 2015 (unless otherwise noted)

INSTITUTION	QUALIFI-CATION	Aeronautical	Agricultural & Irrigation	Chemical/ Environmental	Civil	Computer/Software Engineering	Electrical & Electronics	Maritime	Industrial & Municipal	Mechanical	Mining & Metallurgy	Oil/Gas/Petroleum	Telecommunications	Textile
Public universities														
Ardhi University (ARU)	BSc(Eng)			50 (Env)	51				18					
Mbeya University of Science and Technology (MUST)	BEng				80		59			21				
Sokoine University of Agriculture (SUA)	BSc(Eng)		58											
University of Dar es Salaam (UDSM)	BSc(Eng)		30 (Est.)	67 (Chem)	135 (Est.)	49	13		22	24	63	21 (2017)	54	6
University of Dodoma (UDOM)	BSc(Eng)					106					68	78 (2016)	114	
Public institutes and colleges														
Arusha Technical College (ATC)	BEng				24									
	Diploma	410 - in total			√		√			√		√		
Dar es Salaam Institute of Technology (DIT)	BEng				83	45	67	10 (2017)		29			54	
	Diploma				78	54	61			49	32		67	
Dar es Salaam Maritime Institute (DMI)	BEng							94 - discipline mix not specified						
	Diploma							42 - discipline mix not specified						
National Institute of Transportation (NIT)	BEng	25								38				
	Diploma									529 - discipline mix not specified				
Water Institute (WI)	BEng		54 (2017)											
	Diploma		288											
Private universities														
Kampala International University (KIU)	BSc(Eng)												√	
Ruaha Catholic University (RUCU)	BEng												65 (2014)	
St Joseph University in Tanzania (SJUIT)	BEng				128		127			13 (2017)				
	Diploma				102		96							
St Augustine University of Technology (SAUT)	BSc(Eng)				14		4							
United African University of Tanzania (UAUT)	BSc(Eng)												√	
TOTAL														
Engineer (1 045)		0	88	117	200	155	17	0	40	24	131	99	168	6
Inc. Engineer (1 150)		25	54	0	315	52	253	104	0	101	0	0	119	0
Technician (1 794+410)		0	288	0	333	96	279	42	0	657	32	0	67	0

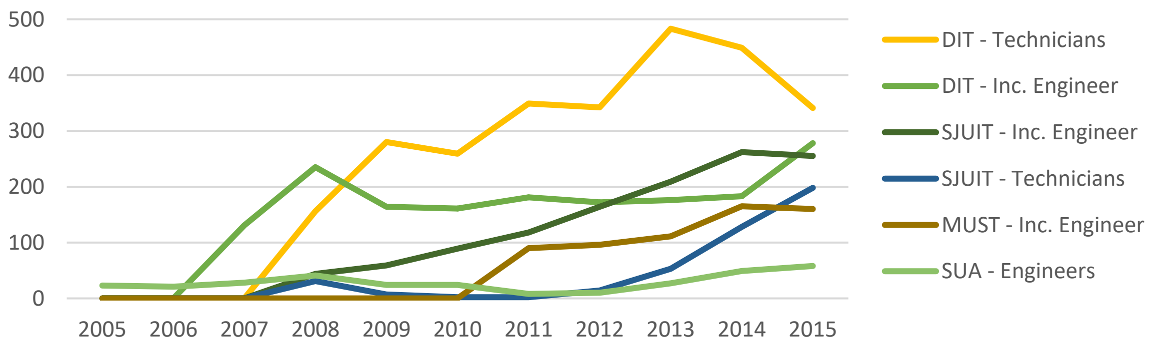


Figure 10: Engineering graduates by institution and category

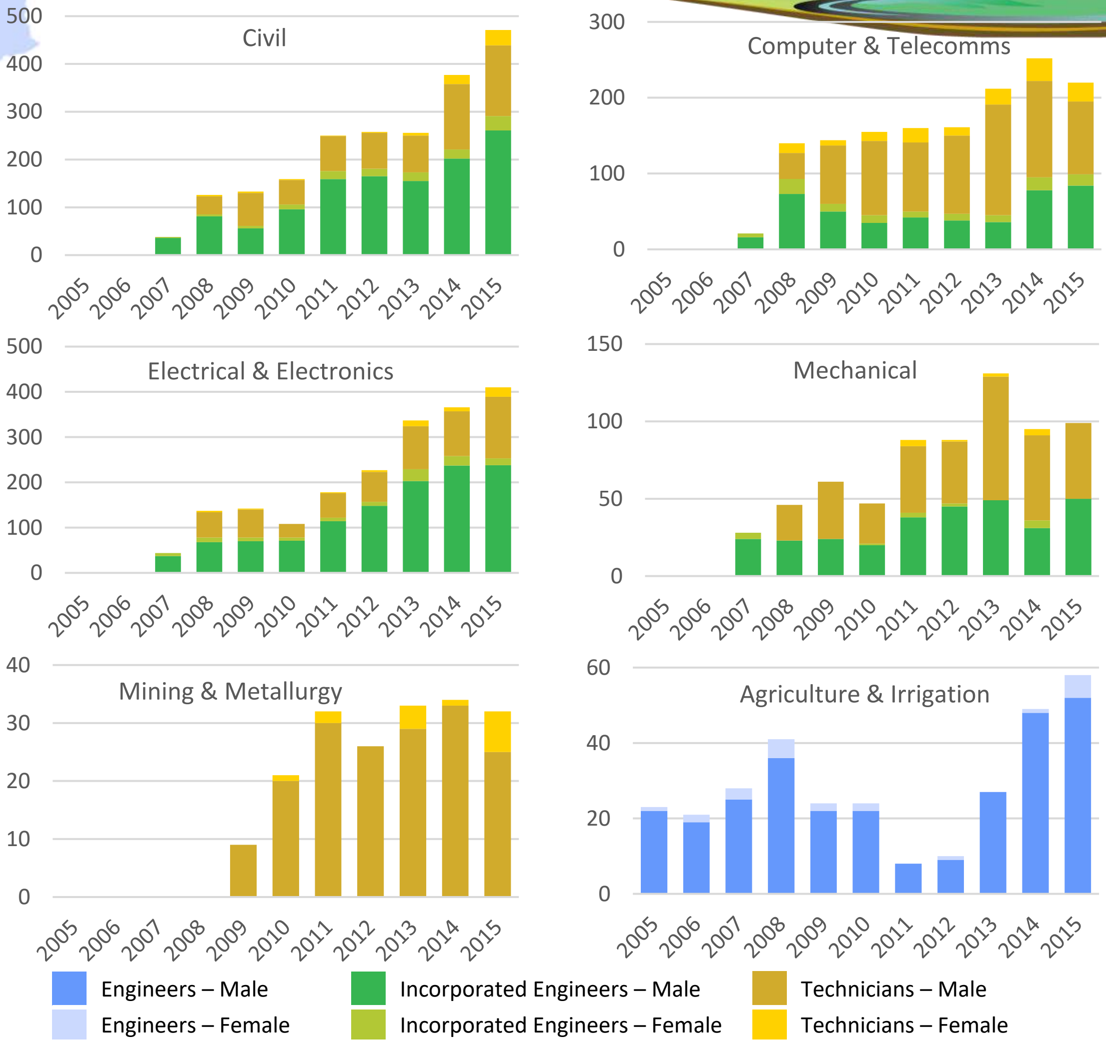


Figure 11: Engineering graduates by discipline, category and gender for selected institutions as per Figure 10

(Many engineers do graduate but historical data for graduate engineers what only available from Sokoine University of Agriculture)

The National Council for Technical Education (NACTE) was established to oversee and coordinate the provision of technical education and training. NACTE regulates, accredits and advises on qualifications in all tertiary education and training institutions other than universities and their affiliated colleges. These institutions offer a four-year BEng for incorporated engineers and a three-year diploma for technicians. It would seem that both bodies need to work with the ERB and use the Washington, Sydney and Dublin Accords as guidelines for accrediting engineering qualifications.

Student mobility

In 2015, a total of 432 Tanzanians were studying at South African universities, of whom 112 were studying at the University of Cape Town. Only three engineering students graduated – two completing degrees and one a national diploma. No one completed BTech qualifications. Numbers graduating in other countries and returning were not readily available.

GRADUATE TRAINING

Once the tertiary education phase is complete, it is necessary for graduates to receive structured training in the workplace, under professional supervision and mentorship, to develop to the level of competence required for professional registration, and to be able to take on work independently.

At the time of independence in 1961, Tanzania boasted only two indigenous engineers. Recognising the need to develop a pool of local engineers, the government took deliberate steps to train engineers and by 1997, there were over 4 000 Tanzanian engineers. However, few were registered with the ERB. In response, the Structured Engineers Apprenticeship Programme (SEAP) funded by the government was launched by the Minister of Works, the Hon. John P. Magufuli, on 13 January 2003. It is supervised by the ERB. It aims to enable Tanzanian graduate engineers wishing to practise engineering to qualify for registration as professional engineers in the shortest possible time. The ERB monitor progress, engage with mentors and review quarterly reports.

Since 2003, a total of 5 300 graduates have been taken on, but unlike in the early years when placements were largely in government, the private sector has slowly but surely taken over funding and offering placements to graduates. Since 2015, just over 2 000 students have been supported by the private sector. This is substantially less than the number who graduated in the same period. Consideration needs to be given to including the need for graduate training in all public sector tenders. Specific initiatives for female graduates are discussed below.

Government departments expressed concern that the requirement for engineers employed in government to be registered with the ERB precluded graduates from being appointed and trained in junior positions. The only way the government could take on graduates was on a contract basis for a two- or three-year period. After the contract, the only way they could remain in government was to have achieved early registration and be able to apply for a vacant post, of which there are very few. There is a need to revisit career paths in government to grow public sector engineering professionals, and for the ERB criteria to be fine-tuned for specific grades of appointments.

PROFESSIONAL REGISTRATION

The National Construction Council (NCC) is an overarching body in the construction sector, which was established for the purpose of spearheading the development of the construction industry. It is responsible for directing and monitoring the work of three regulatory bodies in the sector, namely the Contractors Registration Board, the Architects and Quantity Surveyors Registration Board and the Engineers Registration Board (ERB).

The ERB is a statutory body initially established in 1968 and more recently reconstituted under the Engineers Registration Act, No. 15 of 1997. It is responsible for regulating the engineering activities and conduct of engineers and engineering consulting firms. From 1968 to October 2018, some 23 416 graduates and professionals had registered with the ERB but due to attrition, 16 647 were active in 2018. The Board registers engineers and technologists (termed incorporated engineers), and has recently started registering technicians. Registration statistics for 2018 are shown in Table 5.

Although it is a legal requirement for engineering practitioners to be registered with the ERB, it was found that many in manufacturing, support and advisory roles, who did not take responsibility for engineering decisions were not registered. Estimates of the percentage unregistered ranged from 5% to 50%. For purposes of estimating the number of engineers and incorporated engineers in the workforce a figure of 25% has been used, suggesting that there are some 22 000 active practitioners.

VOLUNTARY ASSOCIATIONS AND CONTINUING PROFESSIONAL DEVELOPMENT (CPD)

The Institution of Engineers Tanzania (EIT) represents the interests of engineers and acts as the voice of engineering in the country. The EIT plays an active role in supporting and developing its members by holding courses, workshops and conferences, by disseminating information and relevant research through various media, and by advising on new technologies that could have positive societal impacts.

Table 5: Practitioners registered with the ERB in 2018

CATEGORY	Agricultural	Chemical	Civil	Electrical & Electronics	Environmental	Mechanical & Electromechanical	Mining & Metallurgy	Telecommunications	Total
Graduate Incorporated Engineer	2	1	208	135	25	136	0	154	661
Graduate Engineer	268	489	3 513	1 335	504	1 098	468	1 753	9 428
Incorporated Engineer	0	2	141	132	20	76	2	35	409
Professional Engineer	82	102	2 252	638	136	724	128	237	4 300
Temporary Professional Engineer	9	13	969	118	6	155	50	80	1 399
Consulting Engineer	3	2	247	33	14	39	3	7	348
Temporary Consulting Engineer	2	0	88	5	3	5	1	0	103
TOTAL	**365**	**609**	**7 419**	**2 397**	**708**	**2 233**	**651**	**2 266**	**16 647**

TANZANIA

The EIT participates in the development of standards and promotes service excellence, calling upon government and its members to develop economically justifiable and environmentally sustainable solutions to improve the quality of life.

The Tanzanian Society of Agricultural Engineers (TSAE) was formed in the 1980s to support the development of agricultural engineers and contribute to national development. In 1991 it published a substantial document, *The Role of Agricultural Engineering in National Development,* and was very active at the time. The Association still draws like-minded people together to consider and promote agricultural engineering innovations, but does not seem to enjoy the support of former years.

Member and corporate voluntary associations expressed concern about limited coordination between bodies.

WOMEN IN ENGINEERING

Tanzania has recognised the need to grow women in engineering. Working with the Royal Norwegian Embassy which has provided financial support to the ERB, the Female Graduate Engineers Capacity Building Programme has been developed to support female engineers to achieve registration as professional engineers. It aims at promoting gender balance in professional training and at empowering women engineers to hold and manage professional responsibilities confidently in government, industry and business. The programme commenced in 2010, and an extension to the initial agreement has been signed to 2020. The SEAP concept as described under *Graduate Training* is used to ensure an adequate range of experience. By July 2016, there were 329 registered female engineers in Tanzania, by comparison with only 96 female engineers registering between 1976 and 2009.

In 2017, the Royal Academy of Engineering, through the Newton Fund, made funding available to the Women in Engineering Chapter of the EIT to work with *WomEng* to implement programmes pioneered by *WomEng*, including high school STEM awareness and university employability, entrepreneurship and skills training for female engineers.

THE WORKFORCE

The estimate of 22 000 engineers and incorporated engineers is assumed. The number of technicians was not forthcoming largely due to the differing perceptions of what constitutes a technician. Figure 12 gives an indication of the age and gender distribution of engineers and incorporated engineers, based on registration with the ERB.

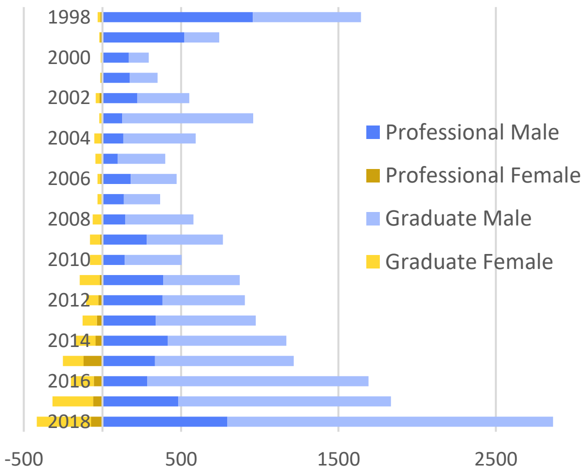


Figure 12: Engineering practitioners in the workforce registered with the ERB by date of registration and gender

THE PRIVATE SECTOR

The main employers in the private sector are consulting, contracting, manufacturing, supplier and mining companies. Lower numbers are employed in small entrepreneurial companies, NGOs, training organisations and other companies where engineering input is required.

Consulting

There are some 205 local consulting engineering practices and 75 foreign-owned companies operating in Tanzania, employing about 540 consulting engineers registered with the ERB along with other engineers, incorporated engineers and technicians. The Association of Consulting Engineers Tanzania (ACET), formed in 1985, represents the interests of many of the local companies. ACET acts as a conduit for the dissemination of relevant information between members, industry associates and clients.

It plays an important role in training, offering scheduled courses, but responds to in-house training requests from members and government departments alike. The courses may be technical or management and performance related. ACET also assists with graduate placements and secondments within the country and with international exchanges when opportunities arise.

ACET has successfully advocated a law that makes it mandatory for foreign firms to partner with local firms in the execution of projects. This, together with capacity building programmes instigated by ACET, has led to the development of the local consulting industry. Strategic alliances and partnerships have allowed many local contractors and consultants to become major players, both locally and regionally.

Of concern to both the consulting and contracting industries is the delay in payments, particularly when working on public sector projects. It is a major problem for small companies.

Contracting

There were some 9 300 contractors registered with the CRB in May 2018, the majority of which are indigenous. The non-indigenous are large foreign contractors which have significant machinery and equipment and are able to access capital.

The CRB is responsible for registering Building, Civil Works, Mechanical, Electrical and Specialist Contractors. Contractors are classified by size, with Class 1 being the largest and Class 7 the smallest. In terms of the classes, only 5% were deemed to be capable of executing contracts valued above US$2 million (the threshold for Class 1).

Of these large-scale firms, 60% were local and 40% foreign. It has been estimated, however, that some 70% by value of the large projects is in the hands of foreign contractors. For each class, the level of engineering and professional staff is specified, as are the plant, equipment and facility requirements.

The Contractors Association Tanzania represents contractors' interests, while the Tanzania Civil Engineering Contractors Association represents the interests of contractors specifically in civil works. The Association of Citizen Contractors Tanzania works towards safeguarding the interests of local contractors.

Manufacturing

There were some 48 000 companies in 2013. In 2014, 432 081 people were employed in the formal manufacturing sector. The Tanzania Investment Centre, a parastatal, was set up to foster economic growth by promoting trade and investment. Various private sector associations represent the interests of manufacturers and the business community, including the Confederation of Tanzanian Industries (CTI) which publishes a detailed annual directory on its members and the products and services they offer.

Mining

In 2013, there were 391 companies in the mining sector, which employed 166 889 people. It is estimated that there are over 1 000 engineers and technicians employed in the sector. The interests of the sector are represented by the Chamber of Mines and Energy.

THE PUBLIC SECTOR

Many engineering practitioners are employed in the public sector. Ministries employing the largest numbers are shown in Table 7. Based on the limited number of questionnaires returned, it is estimated that at least 8 000 engineering practitioners are employed in government, including technicians.

A moratorium on the employment of staff in government was in place for several years. Vacancy levels need to be addressed to rebuild capacity. Salaries also need to be addressed to attract the many engineers who have moved into the private sector, or left engineering in search of better prospects. The process of rebuilding structures is slow, as detailed motivations are required for additional staffing. Furthermore, administration has become top heavy, as administrators are less likely to find alternative opportunities than engineers and have thus remained in the sector.

Of concern, too, is the requirement for all employed in the public sector to be registered with the ERB. This does not allow graduates to be employed and to progress through the ranks, as discussed under *Graduate Training*.

Table 6: Categories and numbers of contractors registered with the CRB in 2018

TYPE	1	1	2	3	4	5	6	7	TOTAL
	FOREIGN	LOCAL							
Building	45	75	46	55	270	819	808	1 640	3 758
Civil	35	38	17	58	246	689	1 238	1 167	3 488
Electrical	24	25	4	9	81	193	110	344	790
Mechanical	14	6	1	4	21	38	44	60	188
Specialist building	6	9	8	10					33
Specialist civil	24	13	40	266					343
Specialist electrical	29	42	112	172					355
Specialist mechanical	37	54	83	192					366
TOTAL	**214**	**262**	**311**	**766**	**618**	**1739**	**2 200**	**3 211**	**9 321**

TANZANIA

Table 7: Ministries employing engineering practitioners

MINISTRY/STRUCTURE
Ministry of Agriculture, Food Security and Cooperatives
Ministry of Livestock Development and Fisheries
Ministry of Defence and National Service
Ministry of Energy • Department of Electricity and Renewable Energy o TANESCO o Rural Energy Agency (REA), including the Rural Energy Board (REB) and the Rural Energy Fund (REF) o Tanzania Geothermal Development Corporation (TGDC) • Department of Petroleum and Natural Gas o Tanzania Petroleum Development Corporation (TPDC) o Petroleum Upstream Regulatory Authority (PURA) o Petroleum Bulk Procurement Agency (PBPA)
Ministry of Finance • Tanzanian and Italian Petroleum Refining Company Limited (TIPER)
Ministry of Minerals
Ministry of Industry, Trade and Investment (MITI) • Tanzania Investment Centre
Ministry of Works, Transport and Communication • Department of Public Works o Tanzania National Roads Agency (TANROADS) o Tanzania Engineering Consulting Unit (TECU) o Tanzania Building Agency (TBA) • Department of Transport o Tanzania Railways Corporation (TRC) o Tanzania–Zambia Railway (TAZARA) o Tanzania Airports Authority (TAA) o Tanzania Civil Aviation Authority (TCAA) o Air Tanzania Company Limited (ATCL) o Tanzania Ports Authority (TPA) o Marine Services Company Limited (MSCL) o Tanzania Meteorological Agency (TMA) • Department of Communication o Tanzania Telecommunications Company Limited (TTC) o Tanzania Communications Regulatory Authority (TCRA) o Tanzania Broadcasting Corporation (TBC)
Ministry of Lands, Housing and Human Settlements • National Housing Corporation (NHC)
Ministry of Natural Resources and Tourism
Ministry of Water and Irrigation • Department of Urban Water • Department of Rural Water • Department of Water Resources • Department of Water Quality • Department of Irrigation • Drilling and Dam Construction Agency (DDCA) • Dar es Salaam Water and Sewerage Authority (DAWASA) • Dar es Salaam Water and Sewerage Corporation (DAWASCO) and 25 other utilities • Energy and Water Utility Regulatory Authority (EWURA)
Ministry of State in the President's Office • Infrastructure Department • Regional Administration, Local Government, Civil Service and Good Governance • Tanzania Rural and Urban Roads Agency (TARURA)

MIGRATION TRENDS

Analysis of the United Nations Population Division statistics for 2015 shows a net loss of professionals from Tanzania. Of those entering the country, 50% were from the DRC. Thirty-eight per cent of professional emigrants moved to the USA, 26% to Rwanda, 11% to Burundi and 8% to the UK and Northern Ireland.

These figures refer only to those who officially emigrated or immigrated. There is ongoing movement of practitioners as projects are awarded to international companies. In October 2018 just over 9% of the professional and consulting engineers registered with the ERB since 1998 held temporary registration, indicating that they would be foreign.

ENGINEERING NUMBERS AND NEEDS

Considering the vacancies and all the developments planned, there is clearly a need for more qualified and well-experienced engineers, incorporated engineers and technicians.

Due to varying views on the roles and qualifications for technicians, projections are based only on engineers and incorporated engineers in the workplace.

In 2015, 1 045 engineers and 1 150 incorporated engineers graduated and would have been ready to enter the industry. Assuming a total number of 22 000 in the workplace, Figure 13 shows the current workforce, the losses that will occur over the 18-year period to 2035 due to retirement, mobility and mortality, and the growth in engineering capacity if local engineering graduations increase at 2% per year over the period.

The blue dotted line shows the growth in skills that would be required at the 2017 GDP growth rate of 6.0% and the green dotted line shows the growth based on the 2018–2023 GDP projection, which is the same at 6.4%.

The number graduating in 2015 exceeds the demand at the projected growth rate and will slightly exceed the Agenda 2063 projections if achieved.

Should there be resolve to fill all vacant posts and use local service providers for projects, the excess will be absorbed. Of concern is the fact that graduation rates have increased beyond 2% since 2015, with graduate numbers having doubled in some institutions by the end of 2017.

(Note: A 70% employment elasticity factor has been used to extrapolate the employment demand.*1)

The benefit of increased numbers will not be realised unless graduates coming into the system are supervised and coached by experienced practitioners to be able to take over from the older cohort which currently carries out much of the engineering work. It is critical that all sectors are involved in the national programme for graduate training, development and succession planning, SEAP.

There are a few mismatches in terms of numbers and needs which may need attention but could simply relate to incorrect data being supplied.

- **Electrical engineering:** Only 17 are shown as having graduated as electrical engineers in 2015. This number is very low given that electrical engineers are required in many sectors. If the numbers are currently so low, more students need to be encouraged to study electrical and electronic engineering.
- **Industrial engineering:** The introduction of Industrial and Municipal Engineering Management as a qualification is applauded to ensure improved management of production processes and municipal services and more students should be encouraged.
- **Mining engineering and metallurgy:** With the growth of the mining industry, mining engineers and metallurgists are key to productivity and quality output. Given the move to smelt and refine concentrates and ore locally, an increased number of metallurgists will be required.
- **Technicians:** There is no unified understanding of the role and qualification requirements for technicians. A decision needs to be made as to whether more technicians with theoretical training are required to carry out basic calculations, handle detailing, oversight of production lines, maintenance and site supervision, or whether more hands-on training is required to supervise teams of artisans, operators and labour. This should be investigated considering the Dublin Accord guidelines. Qualifications offered by higher education institutions and those falling under NACTE should be aligned or differentiated in line with the findings.

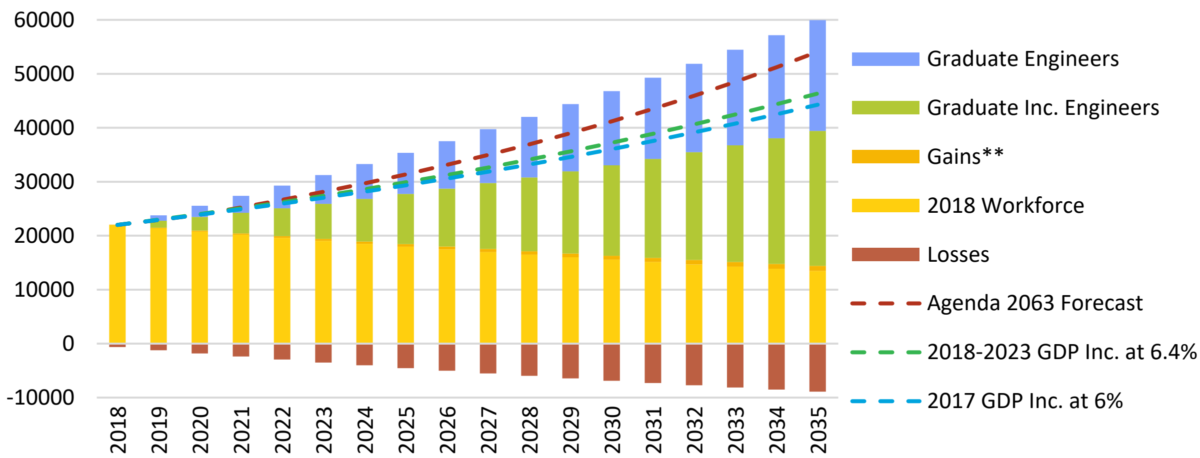


Figure 13: Flow of engineers and incorporated engineers based on a 2% increase in graduation rate per year
***Excludes international engineering practitioners in the country on short-term contracts and not registered with the ERB. Those registered with the ERB are included in the workforce.*

KEY RECOMMENDATIONS

To develop a sound pool of engineering professionals, able to contribute to the well-being of Tanzania, the following should be considered:

Schooling

- **Primary and secondary education:** Address the weaknesses in primary and secondary education, and increase the number completing secondary education with acceptable results.

---

*1 Employment elasticity is a measure of the percentage change in employment associated with a 1% change in economic growth. If the growth is likely to be in agriculture, the percentage could be lower, as growth in that sector generally has to do with productivity gains and not employment, while if the growth is likely to be in high-tech manufacturing, the elasticity factor may be more than 100%. These considerations will need to be factored into Human Resource Demand Planning.

- **Career guidance:** Expand career guidance to attract high-calibre entrants into the engineering profession, incorporating programmes to reach female learners, and rural and low-income areas.
- **Bursaries:** Reprioritise the apportionment of the skills levy and provide bursaries to attract those who excel mathematics and science to study engineering.

Tertiary education

- **Consolidation:** Consolidate engineering studies into well-resourced universities and institutes to ensure quality output.
- **Accreditation:** The ERB, NACTE and the TCU to collaborate on the development of rigorous national accreditation processes using the guidelines of the Washington, Sydney and Dublin Accords.
  - Encourage institutions to develop adequate complex engineering problem-solving content and graduate attributes to satisfy the requirements of the Accords.
  - Withdraw qualifications which do not meet accreditation requirements.
- **Industry liaison:** Liaise with industry on a regular basis to ensure that curricula, methods, software and equipment are relevant and up to date.
- **Curricula:** Provide funding to research, modernise or develop curricula and material where required.
- **Facilities:** Raise funding to upgrade lecture theatres, libraries and laboratory facilities where required.
- **Resources:** Raise funding for computers, engineering software, access to online reference material, and laboratory and other equipment, and ensure adequate support to offer technology-relevant training.
- **Attract and retain academics:** Improve conditions of service, support and packages to attract, retain and appoint additional academics.
- **Academic development:** Provide funding for lecturer post-graduate development and facilitate opportunities for academics to gain experience in industry.
- **Technicians:** Review the need for theoretical or hands-on training for technician qualifications and clearly define the workplace roles for each qualification.
- **Supply and demand:** Investigate the number studying as electrical and metallurgical engineers, and ensure that adequate numbers are enrolled to meet the country's needs.

Graduate training

- **SEAP:** Expand the SEAP programme to ensure that all graduates are adequately trained and update guidelines to include disciplines introduced in recent years.
- **Private sector incentives:** Offer incentives for private sector companies to develop graduates.
- **Public sector support:** Ensure that public sector structures take on and train graduates and that they are absorbed and developed through the ranks.
- **Institutional support:** Institutionalise graduate training in all organisations by setting KPIs for experienced staff to act as supervisors and mentors.
- **Project support:** Make graduate training a requirement of all public sector projects and ensure that the progress of graduates is monitored, and penalties are imposed for non-compliance.

Continuing development

- **CPD:** Support the participation of engineering practitioners in CPD activities.
- **Validation:** Validate short courses and skills programmes for a specified period only to ensure that training remains up to date and relevant.
- **Post-graduate studies:** Provide post-graduate bursaries to develop specialists.
- **Develop managers and leaders:** Encourage industry to continue investing in graduates after professional registration to grow management and leadership capabilities.

Registration of service providers

- **Legislation:** Update and enforce the National Construction Industry Act to:
  - Ensure that there are requirements for consultants and contractors to train graduates, artisans and other construction-related skills.
  - Ensure that international consultants provide all calculations, drawings, operating manuals and other reference material in English.
  - Ensure that local consultants, along with the client, check that design proposals address local needs and customs and that design calculations comply with national codes and standards.
- **Compliance:** Monitor quality and use of local skills (other than *'expatriates whose … skills are not available in Tanzania'*) on all projects and ensure penalties are imposed for poor performance or non-compliance.

Industry wide collaboration

- **Advisory team:** Set up an engineering advisory team, recognised by government, to advise on and endorse infrastructure development proposals, tertiary curricula and graduate training programmes.
- **Collaboration:** Encourage all professional bodies to work together to share knowledge, exchange best practice and ensure coordinated planning of industry support initiatives.

Public sector

- **Economic infrastructure:** Invest in the development of economic infrastructure such as electricity, roads, rail, ports and airports, and address the supply of water services.
- **Maintenance:** Invest in maintenance to preserve new infrastructure and prevent further deterioration of existing infrastructure.
- **Tariffs and payment:** Review and increase tariffs where appropriate, enhance domestic revenue collection and demand management to fund development.
- **Technical capacity:** Reprioritise budgets to fill vacant posts and build technical capacity, ensure that salaries are competitive and develop succession plans to make the public sector an employer of choice.
    - Address employment conditions in the public sector to allow graduates to be appointed into permanent positions and developed through the ranks.
- **Technical decision-makers:** Continue appointing engineering professionals in decision-making post.

ACKNOWLEDGEMENTS

The detailed picture presented would not have been possible without the support of many associations, government departments and local professionals. A special thank you to Tabitha Etutu from the Ministry of Education, Science and Technology and Jubilata Shao from the Ministry of Foreign Affairs, East African, Regional and International Cooperation for providing contacts, organising meetings and chasing data, to Andrew Seleli for the logistical support provided and guidance and to all departments, organisations, Permanent Secretaries, CEOs and senior staff who made time available and provided insights and data.

SOURCES OF INFORMATION

Data and information were gathered during meetings and interviews and via email. SADC reports, master plans and strategies as listed under *Plans and Strategies,* and many standard international sets of data as listed in Chapter 5, *Research Approach,* were also consulted. Further information was gathered from news articles, the Tanzania Invest website and from Labour Force Surveys. Comprehensive documents focusing on specific issues in Tanzania as listed below were invaluable sources of information.

Andreoni, A. 2013. *Mapping Industrial Production in Tanzania. A disaggregated analysis based on the 2013 mainland census.* Vienna: United Nations Industrial Development Organization (UNIDO).

Iimi, A., Humphreys R.M. and Mchomvu, Y.E. 2017. *Modal choice between rail and road transportation: Evidence from Tanzania.* Washington, DC: World Bank Group.

Istoroyekti, Y.M. and Hum, M. 2016. Issues challenging universities: A case of Tanzanian higher education. *Ahmad Dahlan Journal of English Studies (ADJES),* 3(1): 51–62.

Mufuruki, A.A., Mawji, R.M., Kasiga, G. and Marwa, M. 2017. *Tanzania's Industrialisation Journey, 2016–2025*. Nairobi: Moran.

Mwamila, B.L.M., Mkamba, A.O. and Mushi, E. 2004. *Capacity building initiatives by the Engineers Registration Board*. Dar es Salaam: Engineers Registration Board.

Mwamila, B.L.M., Dalmas, N.and Idrissa, B. 2009. *Upgrading of engineering and technology training capacity and capability for Vision 2025*. Dar es Salaam: Ministry of Infrastructure Development.

National Bureau of Statistics (NBS) and Ministry of Industry, Trade and Investment (MITI). 2016. *The 2013 Census of Industrial Production: Analytical report.* Dar es Salaam.

Sutton, J. and Olomi, D. 2012. *An Enterprise Map of Tanzania*. London: International Growth Centre (IGC), London School of Economics.

UNESCO (United Nations Educational, Scientific and Cultural Organization). 2017. *Tanzania and UNESCO. UNESCO National Commission of the United Republic of Tanzania*, 14th edition. London: UNESCO.

ZAMBIA

ZAMBIA is a landlocked country neighboured by the Democratic Republic of the Congo (DRC) to the north, Tanzania to the north-east, Malawi to the east, Mozambique, Zimbabwe, Botswana and Namibia to the south, and Angola to the west.

Zambia is one of the top ten producers of copper in the world, with copper accounting for 11% of the GDP in 2010. The second-largest export product is raw tobacco, accounting for 3% of the GDP.

The capital city is Lusaka which is situated in the south. The population is concentrated mainly around Lusaka and the Copperbelt Province, which are the core economic hubs.

Urbanisation is on the increase with 42% of the population concentrated in a few urban areas along the major transport corridors, while rural areas are sparsely populated. More than 57% of Zambians live below the international poverty line, with rural poverty rates standing at about 80%.

Due to poor planning and lack of investment in housing, cities are expanding through informal settlements. In Lusaka, an estimated 70% of the population lived in informal settlements in 2007. In these areas 89.2% of households had access to safe drinking water, but only 32% had access to private taps. Unemployment in urban areas also presents a major problem.

In 2017, Zambia had the eighth-highest HIV/AIDS prevalence rate in the world with an estimated 6.7% of the population infected, placing a substantial burden on the economy.

THE ECONOMY

Although the largest contributor to the GDP is mining, the non-engineering services sector, including the wholesale and retail trade, education, financial services and tourism sectors, has contributed to around 50% of the GDP for many years.

The economy suffers volatility due to fluctuations in the world copper price, and the ravages of climate change giving rise to extreme droughts or floods. Cognisant of copper price fluctuations, the Zambian government has initiated an economic diversification programme to reduce the economy's reliance on copper, which focuses on exploiting opportunities in agriculture, tourism, gemstone mining and hydropower.

The government also recognises that construction is essential for the continued growth of the economy as it impacts on all sectors.

PLANS AND STRATEGIES

To ensure that these aspirations are met, a number of important plans and development policies have been put in place, the most important of which are:

- **National Vision 2030** which sets out the goals and targets for Zambia to become a prosperous middle-income nation by 2030.
- **Seventh National Development Plan (7NDP) (2017–2021)** which aims to create a diversified and resilient economy for sustained growth and socio-economic transformation, driven by, among others, agriculture. The plan will address

Table 1: Zambian metrics

Population	
Total	16 405 000
Urban	41.8%
Rural	58.2%
Poverty, HIV, Unemployment	
Below the international poverty line	57.5%
HIV-positive	6.7%
Unemployment	7.4%
Human Development Index	0.586
Electricity	
Production kWh	11.55bn
Consumption kWh	11.00bn
Airports and Ports	
Airports	88
- Paved	8
- Unpaved	80
Kilometres of Services	
Roads	40 454
- Paved	9 403
- Unpaved	31 051
Rail	3 126
Oil pipelines	771
Waterways	2 250
Africa Infrastructure Development Index	22.29
Services	
Access to safe drinking water	68%
- Urban	89%
- Rural	52%
Access to improved sanitation	25%
- Urban	35%
- Rural	19%
Access to electricity	26%
- Urban	45%
- Rural	14%
Telephones	101 407
Mobile phones	12 017 034
Internet users	26%

job creation, reduction of poverty, enhanced human development and the creation of a conducive governance environment.

- **Water Supply Investment Master Plan Lusaka** which aims to promote equity in service provision, increase financial self-sufficiency of the Lusaka Water and Sewerage Company and ensure water supply and sanitation service provision in a cost-effective manner.
- **National Strategic Plan for Water (2016–2020)** which aims to ensure improved and sustained service delivery, financial viability for utilities and the operational efficiency of the National Water and Sanitation Council.
- **National Energy Policy (revised in 2008)** which outlined the need to diversify the country's energy mix through the use of Renewable Energy and set generation and connectivity targets to 2030 and the need to manage demand.
- **National Urban and Peri-Urban Settlement Management Programme** which aims to build capacity to strengthen institutions and local communities and ensure effective delivery of housing, infrastructure and services.

ENGINEERING ACTIVITIES

Figure 1 shows the contribution of engineering related economic activities to the GDP. The largest sector is mining followed by construction. Considering each sector in turn will give a picture of the activities, trends, challenges and opportunities for the engineering profession to contribute to the growth of Zambia.

AGRICULTURE

Agriculture is significant for Zambia because of the country's large tracts of well-watered land suitable for different kinds of cultivation and animal husbandry. The country's staple and most cultivated crop is maize. Other major crops include cotton, soya beans, tobacco, groundnuts, paprika, sorghum, wheat, rice, sunflower seeds, coffee, sugar, fruits, vegetables and flowers.

A small number of Zimbabwean farmers were welcomed into Zambia after their expulsion from Zimbabwe who occupy 150 of the more than 740 commercial farms. The skills they brought, combined with general economic liberalisation under the late Zambian president Mr Levy Mwanawasa, have been credited with stimulating agricultural growth. For the first time in 26 years, Zambia exported more maize than it imported in 2004 and has continued to be largely self-sufficient since. The export of cereals, sugar and tobacco contributed just over 6% to the exports in 2016.

Subsistence farming

The majority of the rural population depend on subsistence farming for their livelihoods. Most have limited or no equipment or technology and clear, sow and harvest by hand. In the past subsistence farmers would slash and burn and leave fields fallow for 15 to 20 years to recover. Due to the growing population and demand for land, this is no longer sustainable and a change in farming methods is necessary.

Zambia needs to develop water facilities, irrigation infrastructure and expand the electricity grid to cater for irrigation and assist farmers with getting their products to market. The World Bank approved $200 million credit to support rural development and improve selected rural roads. The project supports the National Development Plan and Vision 2030.

Commercial farming

Medium-scale farmers produce maize and a few cash crops, while large-scale farmers produce crops for both the local and export markets. Sugar, tobacco, cotton and maize are exported in quantity. Vegetables and flowers are increasingly grown for

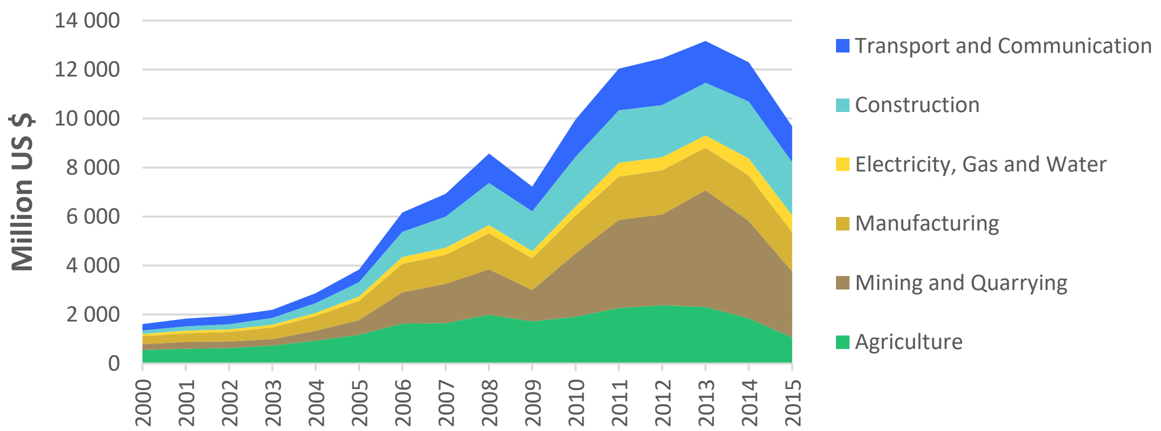


Figure 1: GPD per engineering related economic activity (48% of the GDP)

foreign markets, but to further expand commercial agriculture will require increased investment and access to electricity.

According to the Zambia National Commercial Bank, nearly all commercial farmers want to increase their areas under irrigation, which is supported by Zambia's substantial land and water availability. As supplies from the power sector improve, farms on underdeveloped rainfed land will be able to use electric pumps to access water for irrigation.

Forestry

Zambia has 44 million ha of forest area which, over and above being used as firewood, offers significant input for the timber processing business. Deforestation is a concern due to charcoal and wood fuel production, expansion of small-scale agriculture and unsustainable agricultural practices.

MINING AND QUARRYING

Zambia's natural resources include uranium, silver, cobalt, copper, coal, lead, silver, zinc, emeralds and gold, and its social and economic backbone has always been the mining industry. It is also a global producer of semiprecious gemstones and cobalt. The mining and refining of copper has been of immense importance.

Nationalisation commencing in the early 1970s was aimed at using revenues from the mining industry to strengthen the country. Initially, investments were made in hydropower, railways, roads, schools, hospitals and housing, but little investment continued in the mining industry. As mines needed to go deeper and there was little investment in technology, mining output declined. Furthermore, maintenance and operating costs increased, employment fell and the economy went into decline, along with its existing infrastructure.

From 2000, the mining industry under Zambia Consolidated Copper Mines (ZCCM) was unbundled and sold to private investors. The new owners have invested substantially in their mines, giving rise to an economic upturn, not only on the Copperbelt, but also nationwide. Investments were made in new machinery, new mining methods, and new mineral processing and metal-extraction technologies.

By 2013, after more than US$12 billion of investment, Zambia's copper output had risen nearly threefold and direct employment in the industry had reached 90 000.

In 2014, four main mining operations, namely Konkola Copper Mines (KCM), Mopani Copper Mines, FQM Kansanshi Mine and Barrick Lumwana Mine, together accounted for 70% of copper production. There are, however, many mines that are nearing the end of their lives or are becoming expensive to mine due to the depths reached. Exploration needs to be stepped up to identify the huge potential which still exists. Significant plans are in place to increase existing mining operations, including plans to expand Konkola Copper Mines and to double production at Lubambe Copper Mine, among others.

MANUFACTURING

Zambia's manufacturing and processing concerns are predominately private sector enterprises and include food and beverages; clothing and textiles; timber, pulp and paper; engineering and metal industries; and plastics and chemicals, as can be seen in Figure 3.

The Ministry of Commerce, Trade and Industry has developed an Industrial Policy to support and accelerate industrialisation. The policy is aimed at promoting the production and consumption of local contents. Under the Zambia Development Act, No. 11 of 2006, Multi-Facility Economic Zones and Industrial Parks have been set up to support manufacturing. Unfortunately, these have not

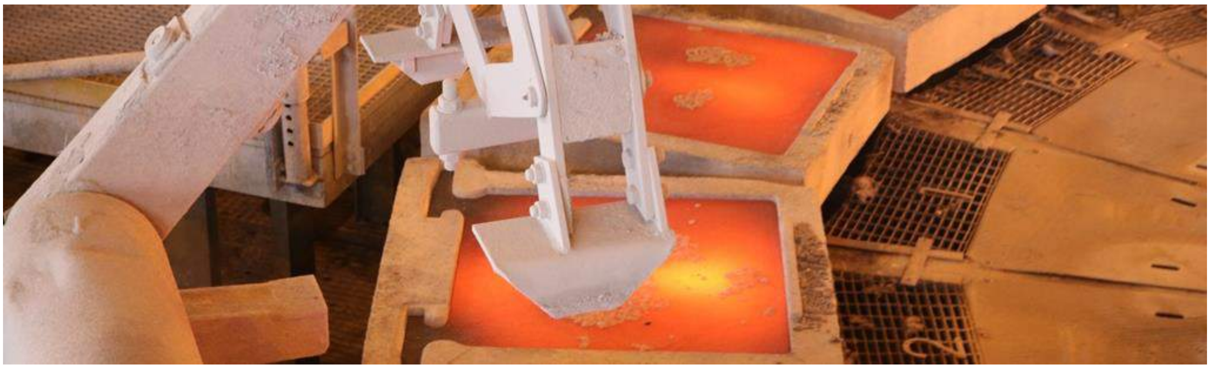


Figure 2: Copper smelting
(Courtesy: First Quantum Minerals Ltd.)

yielded the results expected, with limited numbers of companies setting up per zone.

Food and beverages

Sugars and sugar confectionery are important in the food processing industry. However, sugar production decreased in the 2016/2017 financial year due to drought and power interruptions which restricted irrigation. In 2016, the sugar sector contributed about 3% to the GDP and 6% to the total national exports.

Milling products, groundnuts (including peanuts), cocoa, coffee, tea and milk products are some the many food products processed, as well as fruit, vegetables, meat and fish, which are processed into various forms.

Substantial effort has gone into reducing the importation of edible oils. Initiatives, including edible oil and stockfeed production from soya beans, groundnuts, cotton and sunflower seeds, and palm hearts, have commenced in recent years, the largest producer being Mount Meru Millers.

Zambian Breweries, known as Zambrew, is the biggest brewery. It brews mainly lagers, but is also a major bottler of a range of carbonated drinks under international licence. There are several smaller breweries making largely opaque beer from maize or sorghum.

Zambia has to date exported its raw tobacco crop, and imported cigarette sticks from Kenya and South Africa. British American Tobacco Zambia is currently raising funds to construct a tobacco manufacturing plant in Zambia.

Textiles, clothing and leather

Cotton is grown, ginned and spun in Zambia at industrial sites with state-of-the-art spinning, weaving and processing factories. Products include cotton yarn and grey cloth of world-class quality.

Because of support from government, the textiles and clothing industry grew considerably between 1964 and the 1980s. In 2013, the country harvested 100 000 tons of cotton, which increased to 168 000 tons in 2014 and is expected to increase further due to support and input provided by ginners to cotton growers. This sector has great potential to contribute to the GDP, as well as to create direct and indirect jobs. However, stiff competition posed by the proliferation of cheap textile products, mainly from Asia, poses a serious threat which affects the potential for further investment and growth in this sector.

A range of leather goods, including shoes, are produced locally and tanned leather is exported. In 2006, 1.3 million pairs of shoes were exported, but the number has since dropped.

Timber, pulp, paper and packaging

Sawmilling is a well-developed forestry industry. The supply and manufacture of timber products covers the supply of timber for the construction industry, fuelwood for the tea industry, subsistence utilisation by communities, and the manufacture of furniture, transmission poles, paper and board for the packaging industry.

Plastic, chemicals and other non-metallic mineral products

The plastics industry produces pipes, manhole covers, fittings, roof sheeting, polystyrene, films, carry bags, household goods, furniture, packaging and many other products.

With regard to chemicals, agrochemicals, including pesticides, fungicides and fertilisers, are manufactured in Zambia. Paints, automotive and cleaning chemicals, lubricants and chemicals for food processing and water treatment, among others, are also manufactured. Chemicals for the construction and mining industries are produced, including bitumen, oils and a range of industrial gases such as

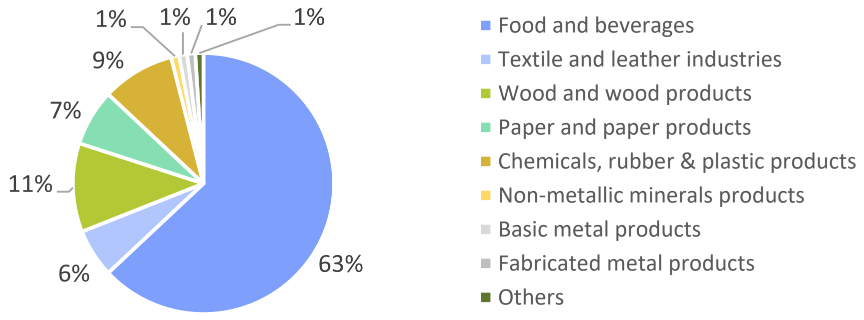


Figure 3: Manufacturing output by subsector in 2013
(Zambia Development Agency. 2013. Manufacturing sector profile.)

oxygen, nitrogen, kerosene (paraffin) and liquefied petroleum gas (LPG).

Zambia has 14 cement manufacturing companies which have contributed immensely to economic expansion by making cement readily available for development. In total, they produced just under two million metric tons in 2016. Capacity has since been expanded and in March 2018 a further producer applied to develop a plant in the Chilanga District.

Pharmaceuticals

Most pharmaceutical companies are engaged in the manufacturing of basic pharmaceutical medicines. Most essential health drugs are imported.

Metal industries, machinery and equipment

Secondary processing of metals is a major activity, including smelting and refining of copper. More recently, the construction of steel mills has made the manufacture of local construction products possible, such as bars, angles, corrugated roof sheeting, etc. Due to increased investment in construction, the demand for steel increased from 200 000 tons in 2011 to 300 000 tons by 2016.

Given the country's mineral wealth, the government has adopted targets for accelerating the growth of engineering product industries, with copper, iron and steel being key areas. Pumps, machinery and many other metal products are manufactured, and motor and plant assembly are also important elements of this sector.

ELECTRICITY, GAS AND WATER

Electricity

Hydropower is a rich source of energy for the country. Major hydroelectric plants are located in the Kafue Gorge, at Kariba and Victoria Falls. The building of the Kariba Dam was a great feat of engineering and the resulting hydroelectric power has been important for the mining industry.

Although power is relatively cheap, in 2013 only 26% of the population had access to electricity, made up of 45% of the urban population and a low 14% of the rural population.

There are three main electricity companies in Zambia:

- **ZESCO Limited** (formerly the Zambia Electricity Supply Corporation), the public utility supplying power to most parts of the country through the national grid
- **Copperbelt Energy Corporation (CEC)** which supplies power to the mines and transmits for the national utilities
- **Lusemfywa Electricity Company** which supplies power to the Central province of Zambia.

The total installed capacity stands at 2 337 MW. Plans are in place to start building two new generation plants in 2018 that will add 550 MW to the grid, a 300 MW thermal power station in the south and a 250 MW hydropower project in the north.

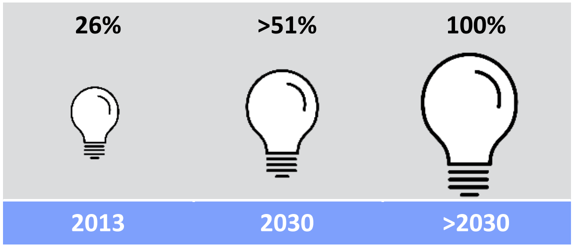


Figure 4: Target dates for access to electricity

To address rural needs, the Rural Electrification Authority (REA) was set up in 2003 and has embarked on an ambitious plan to increase rural access rates to 51% by 2030, as captured in the Rural Electrification Master Plan (REMP). Additional capacity will be generated through extending the national grid and stand-alone electricity supplied from renewable sources such as mini hydropower stations, biomass generation and solar energy.

The transmission network does not cover the whole country. Zambia has initiated plans for transmission inter-connectors with neighbouring countries to expand the network, and the European Union made funds available in 2017 for the upgrading and expansion of transmission and distribution networks in Lusaka.

Private energy companies such as the Zambian Energy Corporation have put additional energy into the grid. They are overseen by the Energy Regulation Board of Zambia.

Oil and gas

Zambia does not produce oil, but samples have shown good traces of crude. The country first discovered reserves of oil and gas near the Angolan border in 2006, and more recently the presence of hydrocarbons was discovered in the Luapula and Northern Provinces. Exploration is continuing.

Water and sanitation

Zambia has many major dams, but several in remote areas were developed for hydroelectric schemes. As a result, only 68% of the population had access to safe drinking water, made up of 89% of the urban population, and 52% of the rural population in 2015. The target for universal access to safe drinking water is 2030 although WASHwatch anticipates that only 75% will be achieved.

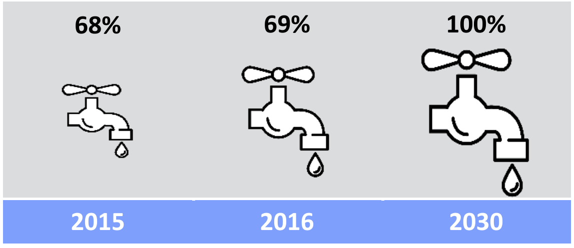


Figure 5: Target dates for access to safe drinking water

The same is not true of sanitation, where only 25% of the population had access to improved sanitation, made up of 35% of the urban population, and 19% of the rural population in 2015.

The target for universal access to improved sanitation is 2030. The rate of progress is, however, extremely slow with WASHwatch suggesting that at the current rate universal access will not be achieved this century.

Water and sanitation services in urban areas are provided by various structures. In 2011, there were 11 commercial utilities owned by local authorities which provide 86% of the services available to urban populations. The balance are serviced by private schemes, mainly companies providing water and sewerage services as fringe benefits to their employees. The size of utilities ranges from 3 000 to more than 75 000 connections.

These arrangements were made possible under the Water Supply and Sanitation Act, No. 28 of 1997, which allows local authorities to establish water supply and sanitation utilities as public or private companies, and allows them to form joint ventures with other local authorities. Nine commercial utilities cover each province, with a further two in the Copperbelt, Nkana and Mulonga covering Kitwe and Chingola respectively.

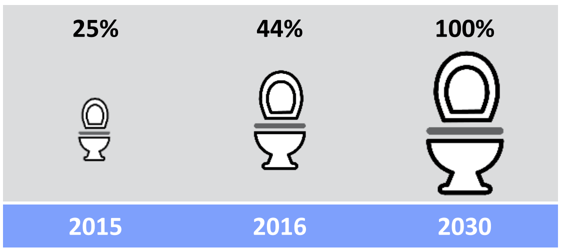


Figure 6: Target dates for access to improved sanitation

Licensed private utilities are Kafue Sugar, ZESCO, Lafarge Cement-Chilanga, Konkola Copper Mines Plc, Kaleya Small Holding Co. and the Zambia Sugar Plc.

All water utility companies operate under the regulations of the National Water and Sanitation Council (NWASCO).

Due to vandalism, lack of maintenance and investment, water and sanitation services are generally inadequate, resulting in households sinking their own boreholes and using septic tanks. Due to lack of planning and control, it is estimated that 80% of borehole water is contaminated as a result of the interaction between underground water and effluent from septic tanks.

To increase water supplies, Lusaka plans to expand bulk capacity, initially adding 50 million litres per day by about 2018, and later a further 600 million litres per day to cater for the population growth expected by 2030. To address sanitation challenges, treatment works will be rehabilitated and/or upgraded, and sanitation networks will be extended.

Considering the rural situation, the National Rural Water Supply and Sanitation Programme (NRWSSP) is gradually being implemented. However, the programme is severely under-staffed and under-resourced. There is a major shortage of skilled staff in government and civil society organisations with the ability and experience to lead and drive the sector.

TRANSPORT AND COMMUNICATION

More than US$5 billion was to be invested in rail and road networks from 2015 to 2020 to support the establishment of new logistics parks to service the mining sectors of the southern DRC and the Zambian Copperbelt.

Roads

Substantial road projects have been planned to reduce congestion in major cities and improve national through routes. The Lusaka Decongestion Project (LDP), which was due to commence in early 2018, is aimed at redesigning the major road network in the city to reduce traffic jams, travel time and travel distances, and to save fuel. The construction of the long-awaited upgrade to the Lusaka-Ndola highway was planned to commence at much the same time and will take four years to complete. This road will improve the flow of traffic and thus economic development, will create more opportunities for agriculture and tourism, and will also cut down on fatalities.

Other projects have included the Link Zambia 8000 Programme, which was aimed at transforming Zambia from being landlocked to landlinked. This involved upgrading some 8 000 km of roads to bituminous standard, the Lusaka 400 Project, comprising 400 km of roads in Lusaka District, and Pave 2000, including the Kazungula Bridge Project, Axle Load Control and the National Tolling Programme.

The 167 km Solwezi–Chingola Road is another important economic road as it supports mining activities in the Copperbelt. Upgrades have been underway for a few years, including bridges, and should be complete by 2018.

Rehabilitation of roads has also been a priority, to gain easier access to the economic potential of many natural resources.

Rail

Zambian railways generally operate well below their original design capacity, but volumes cannot be increased because of poor track condition, lack of locomotive and wagon availability, and limited operating capital.

Disclaimer:
Aurecon gives no warranty of any kind, expressed or implied, with regard to the map or data whether for its reliability, accuracy or completeness and shall not be held liable in any event for any loss or damage in connection with or arising out of the use of this data or map. The Client accepts all inherent limitations of the maps and data, including the fact that the maps and data are dynamic and in a constant state of maintenance, correction and revision. The data and map remain the sole property of the CLIENT and may be used for purposes of this Project with the prior written approval from the CLIENT. aurecon

Figure 7: Transport corridors

The main railway lines are Zambia Railways, which is owned by the government, and the TAZARA line, which links Zambia with Tanzania and is jointly owned by the Zambian and Tanzanian governments. The opening of the Chipata–Mchinji railway link provides connectivity into the Malawi railway network and further connects Zambia to the northern Mozambique railway network.

The Railway Development Agency (RDA) was set up in the second half of 2017 to allow Zambia Railways Limited to concentrate on operations. The Authority's major task will be the rehabilitation and upgrading of railway infrastructure to reach the desired speed of 80 km/h for freight trains and 120 km/h for passenger trains.

Other ambitious plans to link the mining provinces to all regional trade corridors will require private sector funding. Links that have been suggested include:

- **Chingola to Jimbe** on the border with Angola to link to the Lobito Bay port in Angola
- **Kafue to Zawi** in Zimbabwe to link to the Port of Beira in Mozambique
- **Nseluka to Mpulungu** (Zambia's only port on Lake Tanganyika)
- The extension of the **Mchinji–Chipata** Railway line to TAZARA to link to the Port of Nacala in Mozambique
- **Zambia to Namibia** to expand the Walvis Bay–Livingstone–Lusaka–Ndola–Lubumbashi Corridor.

Airports

There are four international airports, five secondary airfields and five airstrips. The government has embarked on a programme to improve the infrastructure at all the international airports to serve as an air cargo hub for the Southern African region. It has installed Smart Airports Systems (SAS) throughout, which rely on digital displays and monitor all activities.

A new Copperbelt International Airport is planned to service the Copperbelt and the north-western parts of the country. This will be the only greenfield international airport development in more than three decades.

Communications

In 1994, the Zambian parliament began the liberalisation of the telecoms sector through the passing of the Telecommunications Act, No. 23 of 1994, which heralded a new era of private participation in the sector.

As of 2016, Zambia Telecommunications Company Limited had 101 407 fixed-line subscribers which represents 0.6% of the population, while three mobile network operators (MNOs), namely Airtel, MTN and Zamtel, boast some 12 017 034 mobile users, translating to 72% of the population.

Consumers have benefited from access to international submarine fibre optic cables, which has resulted in a considerable reduction in fixed-line and mobile pricing. The largest provider of international bandwidth is Fibrecom, a subsidiary of the Zambia Electricity Supply Corporation (Zesco), whose network reaches all 10 provincial capitals and stretches to about 6,000 km. The fibre network infrastructure is built on the electricity pylon. Fibrecom has direct connections to undersea cables through Tanzania, Malawi, Zimbabwe, Namibia, and Botswana.

The government's Universal Access Fund has made significant progress in paying for more than 1 000 base stations to be built. As a result, by mid-2018, mobile coverage had reached 95% of the population. However, internet penetration remains relatively low at 25.5%.

MNOs continue to invest in 3G and LTE-based services, while several ISPs have rolled out WiMAX wireless broadband networks. MTN Zambia has initiated an FTTP programme, initially in Lusaka. These developments are set to increase overall broadband penetration significantly in coming years.

Not only is coverage important, but the sector is also involved in considering innovations and developing Apps to prepare the country for the Fourth Industrial Revolution and the Internet of Things.

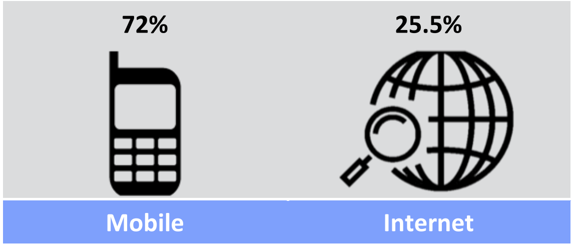


Figure 8: Percentage of population connected to services

CONSTRUCTION

Construction is important in any country due to its ability to create jobs and develop skills. In 2015, the country was described as a construction site because numerous projects in every sector were underway, including the construction of roads, education and health facilities. A conscious effort has been made to offer local employment and training on all construction sites. The aim of the intensive construction is to address national socio-economic development goals such as providing shelter, infrastructure and employment.

Over and above the many projects described above, substantial private sector developments are underway, including the construction of housing, shopping malls, manufacturing facilities, hotels, conference centres and new mines.

Table 2: Major projects identified, or being planned or under construction

PROJECT		VALUE US$	START YEAR	END YEAR
Energy	Batoka Gorge Hydroelectric Power Station (1 600 MW)	$4bn	Feasibility	
	Luapula Hydroelectric Power Station (1 200 MW)		Pre-feasibility	
	Mulembo–Lelya Hydroelectric Power Station		Pre-feasibility	
	Kolwesi–Solwesi Interconnector (Zambia/DRC)		Feasibility	
	Mozambique–Zambia Interconnector		Feasibility	
	Zambia–Tanzania–Kenya Interconnector (ZTK)	$307m	2017	2021
	Zimbabwe–Zambia–Botswana–Namibia Interconnector	$223m	2019	2021
Water	Chirundu Cross-Border Water Supply and Sanitation Project between Zambia and Zimbabwe, including upgrading of treatment facilities	$75m	Feasibility	
	Kasumbalesa Cross-Border Water Supply and Sanitation project between the DRC and Zambia		TBD	
Roads	Rehabilitation of Great East Road from Lusaka to Luangwa Bridge		Seeking finance	
	Rehabilitation of Livingstone–Kazungula–Sesheke Road	$252m	Seeking finance	
	Rehabilitation of T1 from Kafue (Turnpark) to Monze Road		Seeking finance	
	Serenje-Mpika Road	$233m	Seeking finance	
	Upgrading of 321 km of the Lusaka–Ndola Highway	$1.2bn	2018	2022
Rail	Construction of Nseluka–Mpulungu railway spur	$990m	Seeking finance	
	Rehabilitation of Zambia Railway Mainline	$1.3bn	Seeking finance	
Airports	Copperbelt International Airport	$397m	2018	2021

The major projects planned are listed in Table 2. However, due to many past projects being agreed to at inflated prices and the downgrading of the economy by rating agencies, limited funding is available both internally and from the investor community. Few of the projects listed can go ahead without raising substantial funds.

Housing

In 2014, it was estimated that the backlog of housing units in Zambia was about one million and that 110 000 units per year would be required to clear the backlog over the next 10 years.

In the 1996 National Housing Policy (NHP) the government committed to spending 15% of the national budget per year to service land and address the national housing deficit, but it has only been spending about 1% a year on this. A revised policy being developed is expected to address implementation.

LOCAL GOVERNMENT

The are 89 councils making up local government structures – four city councils, 15 municipal councils and 70 district councils. In general, city councils are located in urban districts with large populations and diversified economic activities, while municipal councils cover the suburban regions. District councils are located in relatively rural districts with smaller populations who rely on agriculture and these councils have fewer local tax revenue resources.

Although ZESCO provides the electricity and the utilities provide water to consumers, the Local Government Act, No. 22 of 1991, stipulates 63 functions that councils must discharge, about half of which focus on planning, investment in, and maintenance of, infrastructure.

Local government engineering departments are responsible for town planning, planning of all services and ensuring that utilities develop and maintain the services required. In addition, engineers must develop and maintain roads, bridges, ferries, watercourses, bus stations, street and traffic lighting and public transport services, firefighting and prevention services.

Councils must also provide and maintain drains and sewers, and dispose of sewage and refuse. They must also maintain and establish amenities, including education and health institutions, recreational facilities, libraries, museums, cemeteries, crematoria, etc.

EDUCATION, TRAINING AND PROFESSIONAL DEVELOPMENT

Education and training is a vital part of developing engineering capacity. All elements, from teaching appropriate subjects at schools to continuing professional development (CPD) need to be in place to educate, train and ensure that engineering personnel remain abreast of the latest technology, challenges and emerging solutions.

PRIMARY AND SECONDARY EDUCATION

Primary education starts at Grade 1 and ends at Grade 7 at which stage pupils sit the Certificate of Primary Education (CPE). Primary education is free. Grades 8 and 9 are known as Junior Secondary and end with the Junior Secondary Education Exam. The final exams are taken at the end of Grade 12, known as the Senior Secondary Exam.

Schools in rural areas suffer from a shortage of classrooms and many need significant refurbishment. Often teaching is done in shifts due to the shortage of teachers. Educational resources such as textbooks and teaching aids are also in short supply.

The poor state of Zambia's education system was reflected by the performance of Grade 6 students in the Southern and Eastern Africa Consortium for Monitoring Educational Quality (SACMEQ) tests. Zambia scored the lowest average mathematics and reading scores of the 15 countries surveyed in 2007.

Even though more students are now finishing primary and secondary education, the standard is very low and constitutes a challenge for increasing the number entering engineering and other professions requiring proficiency in mathematics and science.

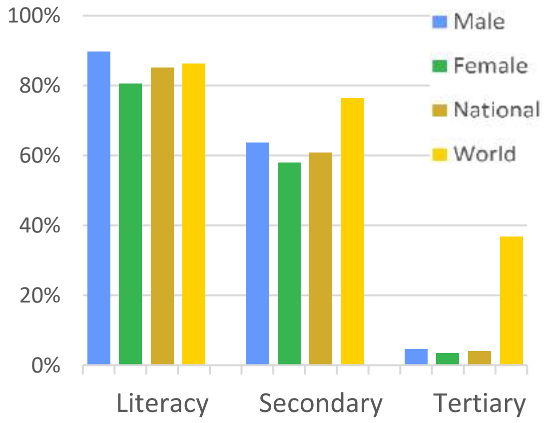


Figure 9: Literacy and enrolment statistics
(only lower secondary included)
(UNESCO from 2012 to 2015)

TERTIARY EDUCATION

Until recently, the country only had two main universities, the University of Zambia and the Copperbelt University, both public. However, to increase access to tertiary education, the establishment of private universities has been encouraged. By 2016, 58 private universities had been established and were recognised by the Zambia Qualifications Authority (ZAQA). The number of public universities has also increased to six.

Over the years, competition for entry into the two public universities was extremely high, resulting in very few high school students entering university. This has meant that the number of university graduates has remained low in most disciplines. In 2008, Mulungushi University was the third public university to open. Copperstone University is a new private entity which gained its charter in 2011. Both universities have started offering engineering qualifications but have not yet been accredited, which means that graduates will not be able to register as professionals in the future.

Students entering degree programmes must complete their one-year A-levels at university as the first year of a five-year engineering degree. Industrial attachment takes place during the third- and fourth-year vacations.

The Technical Education, Vocational and Entrepreneurship Training Authority (TEVETA) was set up to respond to the requirements of the industry's needs in terms of skills. It monitors and regulates skills training and registers over 300 TEVET colleges which offer several qualifications. These include the Trade Test, a Craft Certificate, an Advanced Certificate for technicians and a Diploma for technologists. The trade test route offers courses and certification for those with Grade 9 or in recognition of years of prior experience. The other qualifications require Grade 12 for entry.

It would seem that the Advanced Certificate qualification is a level lower in terms of theory and complexity than that offered in other countries. Qualifications include mechanical draughting, refrigeration, heavy equipment repair, etc. Practitioners with these qualifications tend not to register professionally and have not been included in the graduate numbers.

The National Resources Development College and Northern Technical College (NORTEC) offer engineering qualifications all the way up to diplomas – NORTEC is a major training centre for the mining industry. The Lusaka Business and Technical College (LBTC) has recently started offering advanced certificates but no students have yet qualified, hence the acronym NQ in Table 3 for None Qualified, and the Livingstone Institute of Business and Engineering Studies (LIBES) will offer engineering diplomas from 2019. The ZESCO Training Centre in Ndola previously trained technicians, but now relies on the many colleges for technician training and is rather concentrating on the training of craftspeople.

In addition, the mining companies have in-house training colleges at which they train for their own needs. Colleges at Kitwe, Kalumbila, Mufulira and Mopani offer advanced certificates. The Zambia Information and Communications Technology Authority (ZICTA) also has a training college for the communications sector.

To better equip colleges and enhance the quality of training for craftspeople, artisans, technicians and technologists, the government introduced the Skills Development Levy Act, No. 46 of 2016. Since 2017 employers pay a levy of 0.5% of the payroll towards strengthening the TEVET sector. It is hoped that these funds will be used to enhance facilities and lecturing capacity, among others.

Table 3 shows the institutions and qualifications offered. Where individual numbers were not provided, but a qualification was in place, a tick is shown. Where numbers were estimated during telephone conversations, they are marked as Est. The graduation statistics per institution are shown in Figure 10 and the split by discipline, category and gender is shown in Figure 11.

With regard to higher education, industry has expressed dissatisfaction with graduates, stating that they lack relevant skills. They complain that changes in technology which have been adopted in industry are not reflected in the education curriculum.

Funding under the first phase of the Royal Academy's Higher Education Partnerships for sub-Saharan Africa (HEPSSA) was made available in 2015. In response to this and the above findings, Zambia elected to use the funds to increase student industrial placements, establish academia-industry staff exchanges and enhance industry-based software usage by students. The partnership seeks to promote collaboration and knowledge sharing among regional universities. Funding from the World Bank in 2015 allowed the University of Zambia to develop a materials laboratory for civil engineering students, but adequate laboratory facilities for mining engineering are still lacking.

ZAMBIA

Accreditation

ZAQA, which became an official entity after the enactment of Act No. 13 of 2011, is responsible for setting up and managing the national qualifications framework, registration and accreditation of qualifications, and ensuring that standards and registered qualifications are internationally comparable. The Higher Education Authority (HEA) handles the accreditation process of all higher education qualifications on ZAQA's behalf. In the case of engineering qualifications, the Authority calls on professional bodies to recommend experts to assess qualifications being submitted for accreditation. Technician and technologist qualifications offered through TEVET colleges are accredited by TEVETA.

Table 3: Engineering graduations in Zambia in 2015 (unless otherwise noted)

INSTITUTION	Start year	Agricultural	Chemical	Civil & Construction	Computer Engineering	Electrical, Electronics & Telecoms	Environmental	Mechanical	Mining & Metallurgy
Degree									
Copperbelt University (CBU)	1989		28 (2012)	32		63	25 (2012)	47	53 (2012)
Copperstone University (Private)	2004								√
Mulungushi University (MU)	2008			√	√				
University of Zambia (UNZA)	1969	2		29		25		27	20 (Est.)
Diploma									
Copperbelt University (CBU)	1989		22 (2013)	42	38 (2010)	63			58 (2013)
Luanshya Technical and Business College	1958					30 (Est.)			
Natural Resources Development College (NRDC)		21		39 (Water)					
Northern Technical College (NORTEC)	1956				9	94		52	
Advanced Certificate									
Lusaka Business and Technical College (LBTC)						NQ		NQ	
Northern Technical College (NORTEC)	1956				8	42		37	
Kabwe Institute of Technology						√		√	
Mansa Trades Training Institute	1950					20 (Est.)			
TOTAL									
Engineer (351)		2	28	61		88	25	74	73
Technologist (468)		21	22	81	47	187		52	58
Technician (107)					8	62		37	

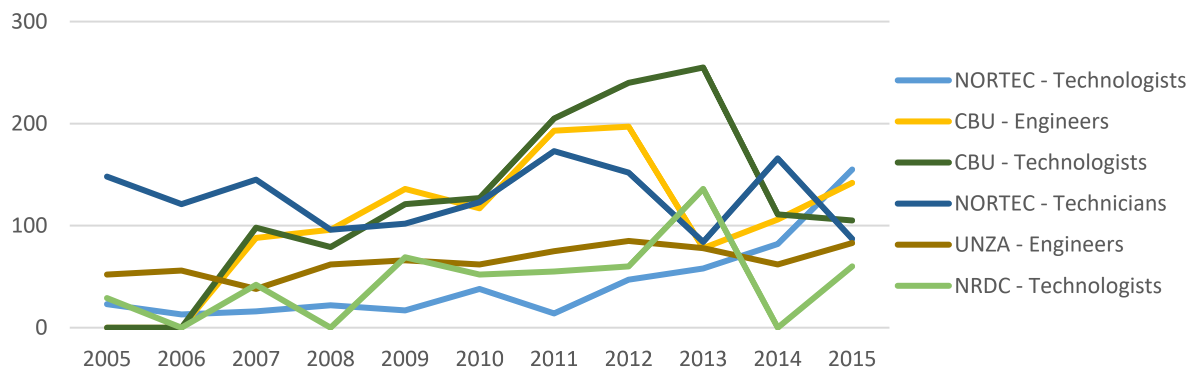


Figure 10: Engineering graduates by institution and category

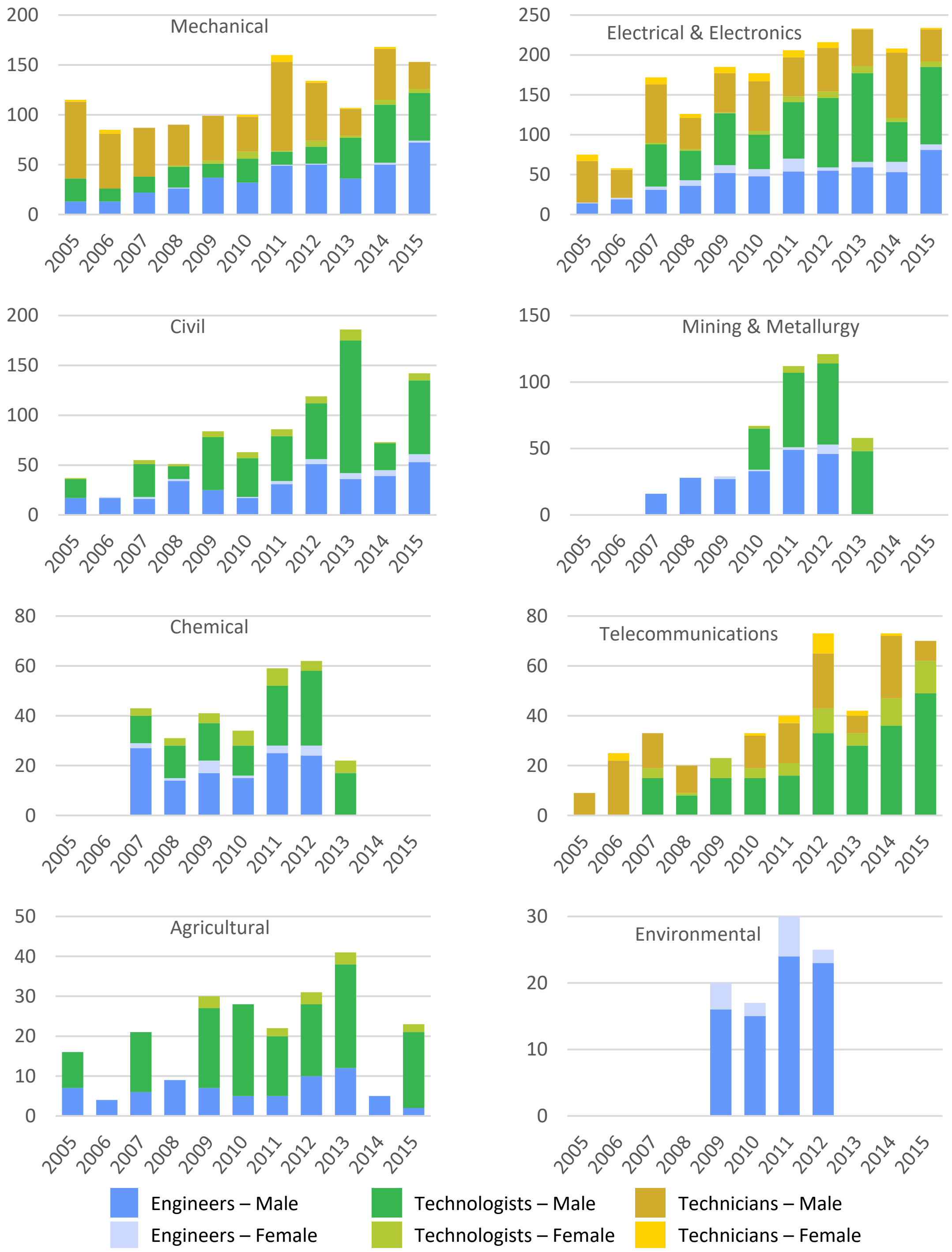


Figure 11: Engineering graduates by discipline, category and gender from selected institutions as per Figure 10

Student mobility

In 2015, a total of 1 913 Zambian students were studying at South African universities, of whom 763 were studying by correspondence through the University of South Africa, and 193 were studying at the University of Cape Town.

A total of 16 engineering students graduated – nine completing degrees, six completing BTechs and one completing a national diploma, indicating that the majority of Zambian secondary school leavers wishing to study engineering choose local universities for tertiary studies. Numbers graduating in other countries and returning were not readily available.

GRADUATE TRAINING

Once the tertiary education phase is complete, it is necessary for graduates to receive structured training in the workplace, under professional supervision and mentorship, to develop to the level of competence required for professional registration, and to be able to take on work independently. As in most countries, the formal graduate training of the past has all but disappeared. Apart from the structured training offered by a few parastatals, little support is offered in the training of graduates.

To encourage the private sector to offer comprehensive graduate training, it has been proposed that the government should issue training guidelines and reward service providers for taking on and training graduates by offering one or more public sector contracts of magnitude linked to the number of graduates the company has taken on.

The Engineering Institution of Zambia (EIZ) has set up a working group to consider mentorship, coaching, apprenticeships and internships, and to formulate a mentoring model. The challenge is the reduction in government spending and the limited work opportunities on which to train graduates.

PROFESSIONAL REGISTRATION

The Engineering Institution of Zambia (EIZ) was founded in 1954 to look after the interests of the engineering profession and became a statutory body through an Act of Parliament in 1972. Later it was governed by the EIZ Act, No. 27 of 1992, which has since been replaced by the EIZ Act, No. 17 of 2010.

One of the key features of the 2010 Act was the creation of the Engineering Registration Board (EngRB) to register individuals and companies practising engineering in Zambia. Individuals include craftspeople, technicians, technologists and engineers. The EIZ Council is responsible for membership activities, the EngRB for registration to regulate engineering practice, and the Disciplinary Committee, is responsible for the conduct of members. The EngRB has a team of inspectors checking on projects and companies to ensure that they retain the level of skills for which they were registered and to maintain standards.

Membership of the EIZ is compulsory by law before practitioners may apply for professional registration with the EngRB. A total of 3 115 professionals were licensed to practice in 2016, as shown in Table 4 which is about 55% of all professionals that had registered with the EngRB since its inception.

Table 4: Professionals registered with the EngRB in 2016

DISCIPLINE	ENGINEER	TECHNOLOGIST	TECHNICIAN
Agricultural	16	6	0
Chemical	70	11	1
Civil	948	170	27
Computer	30	5	6
Electrical	472	182	224
Mechanical	351	158	225
Metallurgical	64	20	-
Mining	115	14	-
TOTAL	**2 066**	**566**	**483**

Membership and registration numbers fluctuate significantly with the fortunes of the copper price and the construction industry. When active, many foreign practitioners apply for permits, but leave when either sector slows down and their contracts are terminated.

In 2017, the number of practitioners who had joined the EIZ since inception was 23 341, made up of 11 818 engineers, 6 066 technologists and 5 457 technicians. Assuming that 55% of these are active, then this suggests that a total of 12 800 practitioners were active in the workforce that year.

VOLUNTARY ASSOCIATIONS AND CONTINUING PROFESSIONAL DEVELOPMENT (CPD)

As outlined above, the EIZ is a learned society which supports the engineering community by providing CPD through learning opportunities such as conferences, symposia, forums, meetings and workshops, etc.; publishing professional journals and magazines; and providing networks for professionals to meet and discuss their fields of expertise. The EIZ is broken into two regional structures, each with district committees which organise events, and there several sections, which represent discipline or category interest groups.

WOMEN IN ENGINEERING

Female members of the EIZ have driven the establishment of the Zambia Women in Engineering Section (ZWES) to increase the participation of women in engineering activities and also encourage more girls to take up engineering as a career. The section was inaugurated at the 2017 AGM of the EIZ, and the women campaigned enthusiastically to ensure that in 2018 many women were elected onto regional committees. They are anxious to see a female president being elected in the next couple of years.

THE WORKFORCE

Considering the EIZ data, suggests that there were about 12 800 active engineering practitioners in Zambia in 2017.

THE PRIVATE SECTOR

The main employers in the private sector are consulting, contracting, manufacturing, supplier and mining companies. Lower numbers are employed in small entrepreneurial companies, NGOs, training organisations and other companies where engineering input is required.

Consulting

The Association of Consulting Engineers of Zambia (ACEZ) represents the interests of consulting engineers. The EIZ Act of 2010 requires that Consulting Engineers practising in Zambia are registered with the EngRB and must be members of the ACEZ. There were 76 consulting firms registered with the ACEZ in 2018, ten of which were sole practitioners, three associate members and the balance larger, generally multi-disciplinary companies covering structural, civil, mechanical, electrical, geotechnical, environmental and chemical engineering, and project management. It was estimated that between them these firms employ some 400 to 500 engineering practitioners.

Contracting

There are some 5 600 contactors registered with the National Council for Construction (NCC), which is a statutory body set up under the National Council for Construction Act, No. 13 of 2003. Under the Act, the NCC is charged with registering contractors and professional bodies or organisations whose members are engaged in activities relating to the construction industry. According to the 2014 Labour Force Survey, 182 806 people were employed in the sector.

It was recognised that for development to be sustainable and well coordinated, it was important for a body representing all issues relating to the construction industry to be in place. The National Policy on the Construction Industry (NPCI) sets out the government's aims and objectives for the industry, which are primarily to enhance delivery and ensure value for money, growth of the emerging construction sector, sustainability, and increased capacity and employment opportunities. The range of contractors is shown in Table 5, where Grade 1 represents the largest contractors and Grade 6 the micro-contractors. Contractors are graded according to their technical capacity, personnel, equipment and other resources and experience. Training is offered to the lower grades to assist them to grow and move into the higher categories.

As with the EngRB, inspections are carried out to ensure quality and safety on site, and that contractors are working at the correct grade. A register of contract details is also maintained to understand the industry and the level of foreign involvement, with the aim of increasing the share of business given to local contractors and suppliers.

Local contractors are not convinced that the system supports them, complaining that they rarely get awarded significant contracts. These are usually given to international companies which can afford to buy the tender documents, pay the 2% guarantee bond and that own substantial machinery and equipment. Without winning contracts, local contractors cannot afford to own machinery and equipment, but must rent, putting a premium on their costs. Furthermore, they run into cash flow problems due to the frequent tardiness of payment. They also complain that winning firms bid so low that the quality of work is sacrificed, but penalties rarely seem to be enforced. These firms also pay workers below the minimum wages and conditions on site are unsafe and unhealthy.

In 2017 more stringent work permit conditions were imposed in the spirit of the Zambianisation policy, to limit the issue of permits for skills not available locally, and demands that foreign professionals transfer skills to Zambians during their tenure in country.

Various contracting voluntary associations, such as the Association of Building and Civil Engineering Contractors (ABCEC), the National Association of

Table 5: Contractors registered with the NCC in Zambia, 2018

CATEGORY / GRADE	1	2	3	4	5	6	TOTAL
B – General Building and Housing	70	69	51	253	443	1 637	2 523
C – General Civil Engineering Works	53	29	12	44	80	327	545
E – General Electrical and Telecoms	40	22	18	39	90	278	487
M – Construction Works within Mining Areas	12	10	3	20	35	304	384
Me – Mechanical Engineering Works	6	2	1	3	5	73	90
R – General Roads and Earthworks	67	32	31	107	311	1 076	1 624
TOTAL	**248**	**164**	**116**	**466**	**964**	**3 695**	**5 653**

Medium and Small-Scale Contractors (NAMSSC) and the Zambia Association of Women in Construction (ZAWIC), attempt to represent their members' interests in the national debate.

Manufacturing

According to the 2014 Labour Force Survey, 223 6816 people were employed in this sector. The Zambia Development Agency (ZDA), a parastatal, was set up to foster economic growth by promoting trade and investment. Various private sector associations represent the interests of manufacturers and the business community, including the Zambia Association of Manufacturers, the Zambia Chamber of Small and Medium Business Associations and the Zambia Chamber of Commerce and Industry.

Mining

According to the 2014 Labour Force Survey, 82 729 people were employed in the mining sector. There are 12 major copper mines, and many smaller and artisanal mines. The largest four produce over 70% of Zambia's copper and employ hundreds of engineers, but report vacancy rates of over 30%. The range of engineers used include mining, metallurgical, chemical, electrical and mechanical, with lower numbers of civil and electronic engineers. Engineers are recruited from around the world. Those recruited locally have been trained at the University of Zambia or the Copperbelt University.

The industry complains that local training does not adequately cover their needs or the latest technologies. There is a need for the universities and the sector to work together to update curricula, and for mining houses to help with equipping laboratories and training staff in the use of the latest equipment. As with the Royal Academy project, it is suggested that the sector facilitate industrial attachments for academic staff to become *au fait* with current best practice.

Hundreds of technicians and technologists are also employed in the copper sector. NORTEC appears to be the main training ground, with some staff coming from the Kabwe and Mansa Institutes (previously trade schools). These institutions also need support from the sector.

It is estimated that there are more than 1 500 engineering practitioners employed in the sector. They are to be found in the copper mines, smelters, the mining of other commodities, and in quarrying and cement production.

The Chamber of Mines of Zambia (CMZ) has represented the interests of the mining industry in one way or another since 1942. It has 30 main members, classified as Class A, B, C or D depending on the size of mining operation or the type of work performed. There are six major copper mining companies in Class A, six smaller ones in Class B, non-ferrous mining organisations in Class C and 13 of the major mine suppliers in Class D.

THE PUBLIC SECTOR

Many engineering practitioners are employed in the public sector and in local government. The departments that employ substantial numbers of engineering practitioners are shown in Table 6.

Unlike in other countries in the region, there were limited reports of vacancies but there were complaints of positions requiring experienced engineering practitioners being filled with inexperienced cadre, which was a frustration.

Table 6: Ministries employing engineering practitioners

MINISTRY/STRUCTURE
Ministry of Agriculture and Cooperatives
Ministry of Commerce, Trade and Industry • Zambia Development Agency (ZDA)
Ministry of Communications and Transport • Tanzania-Zambia Railway Authority (TAZARA) • Zambia Railways Limited (ZRL) • Roads Development Agency (RDA) • Zambia Information & Communications Technology Authority (ZICTA) • Zambia Telecommunications Company Limited (ZAMTEL)
Ministry of Defence
Ministry of Energy and Water Development (MEWD) • Water Resources Management Authority (WARMA) • National Water and Sanitation Council (NAWASCO) • Zambia Electricity Supply Corporation (ZESCO) • Rural Electrification Authority (REA) • Zambezi River Authority
Ministry of Environment, Natural Resources and Tourism
Ministry of Finance and National Planning • Industrial Development Corporation
Ministry of Lands
Ministry of Local Government and Municipalities
Ministry of Mines and Minerals Development
Ministry of Science, Technology and Vocational Training
Ministry of Works and Supply • Department of Preventative and Maintenance Services
Ministry of Housing and Infrastructure Development • Department of Planning Research and Monitoring • Department of Housing Development • Department of Infrastructure Development

Most parastatals and large engineering departments offer graduate training, but the extent of these programmes is insufficient to absorb all the graduates requiring structured training.

MIGRATION TRENDS

Analysis of the United Nations Population Division statistics for 2015 shows a net loss of professionals from Zambia. Of those entering the country, 30% were from the DRC. Twenty-seven per cent of professional emigrants moved to South Africa, 18% to Malawi, 17% to the USA and 12% to the UK and Northern Island. These statistics relate to those who have officially immigrated or emigrated. There is, however, a constant flow of engineering skills as contracts are awarded to international contractors, which enter on a temporary basis. Chinese nationals constituted some 11% of registered professionals active in 2016, and Asian nationals a further 7.5%.

ENGINEERING NUMBERS AND NEEDS

It is evident that engineering practitioners play a key role in the economy of Zambia and could make a much more significant contribution if investments increase.

To determine the number of practitioners in the engineering workforce, EIZ estimates and data from a limited number of returns from public and private sector organisations were used. The EIZ estimates vary between 10 000 and 14 000, depending on the state of the economy. An average of 12 000 has been used. Employment per sector in 2018 is suggested in Table 7. There should be viewed as rough estimates.

Table 7: Estimated numbers of engineering practitioners in the engineering workforce

SECTOR	ESTIMATED NUMBER
Academia and research	400
Agriculture	300
Consulting	500
Contracting	1 100
Government	2 700
Graduates in training	500
ICT, systems and telecommunications	500
Manufacturers and suppliers	3 800
Mining	1 600
Miscellaneous and NGOs	600
TOTAL	**12 000**

Annually about 350 engineers, 470 technologists and 110 technicians graduate in Zambia, but with more higher education institutions starting to offer engineering qualifications, an additional 100 or more are likely to graduate by 2020. The number is augmented by graduates returning from studies in South Africa and elsewhere.

Figure 12 shows the current workforce, the losses that will occur over the 18-year period to 2035 due to retirement, mobility and mortality, and the growth in engineering capacity if engineering graduations increase at 2% per year over the period.

The blue dotted line shows the growth in skills that would be required at the 2017 GDP growth rate of 3.4% and the green dotted line shows the growth based on the 2018–2023 GDP projection of 4.4%. A 70% employment elasticity factor has been used to extrapolate the employment demand.*[1]

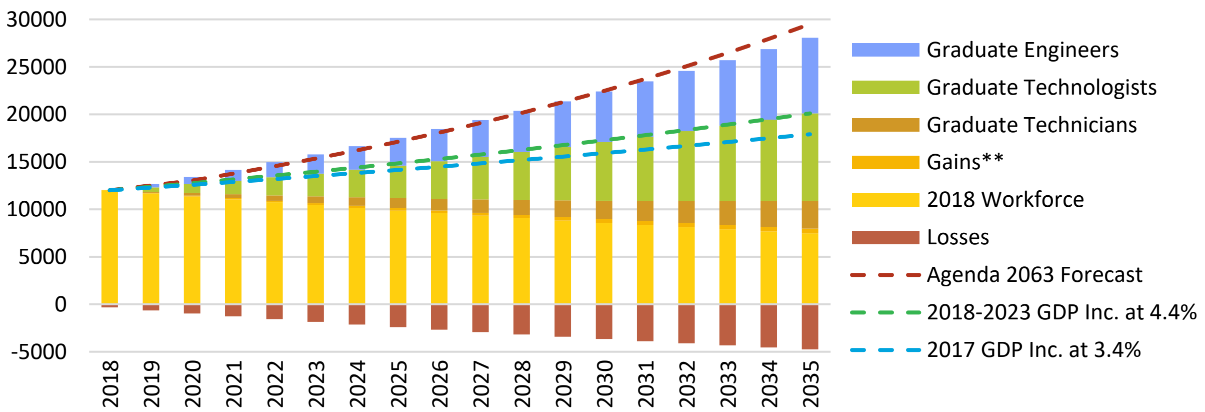


Figure 12: Flow of engineering skills based on a 2% increase in graduation rate per year

***Excludes international engineering practitioners in the country on short-term contracts and not registered with the EngRB. Those registered with the EngRB are included in the workforce.*

*[1] Employment elasticity is a measure of the percentage change in employment associated with a 1% change in economic growth. If the growth is likely to be in agriculture, the percentage could be lower, as growth in that sector generally has to do with productivity gains and not employment, while if the growth is likely to be in high-tech manufacturing, the elasticity factor may be more than 100%.

ZAMBIA

At the 2017 growth rate and the projected growth of 4.4% there will be an excess of graduates, but should the Agenda 2063 growth be achieved, the graduation rate will match the demand. The number of graduates relative to experienced staff in the workplace will be high and rigorous structured programmes will be needed to ensure that graduates are adequately trained to become independent professionals.

When prioritising the approval of new courses and admissions to existing qualifications, consideration should be given to increasing the number of agricultural engineers being trained in view of the country's dependence on agriculture, and the number studying civil engineering in view of the large infrastructure projects being planned.

More rigorous assessment of supply and demand should be carried out before making such decisions as, sadly, the data made available to the research team was inadequate to draw comprehensive conclusions.

KEY RECOMMENDATIONS

To develop a sound pool of engineering professionals, able to contribute to the well-being of Zambia, the following should be considered:

Schooling

- **Primary and secondary education:** Address the weaknesses in primary and secondary education, and increase the number completing secondary education with acceptable results.
- **Career guidance:** Expand career guidance to attract high-calibre entrants into the engineering profession, incorporating programmes to reach female learners, and rural and low-income areas.
- **Bursaries**: Provide bursaries to attract those who excel in mathematics and science to study engineering.

Tertiary education

- **Accreditation:** EngRB to work with HEA to develop rigorous national accreditation programmes to ensure the quality of engineering education using the guidelines of the Washington, Sydney and Dublin Accords.
    - Encourage institutions to develop adequate complex engineering problem-solving content and graduate attributes to satisfy the requirements of the Accords.
- **Industry liaison:** Liaise with industry on a regular basis to ensure that curricula, methods, software and equipment are relevant and up to date.
- **Curricula:** Provide funding to research, modernise or develop curricula and material where required.
- **Facilities:** Raise funding to upgrade lecture theatres, libraries and laboratory facilities where required.
- **Resources:** Raise funding for computers, engineering software, access to online reference material, and laboratory and other equipment, and ensure adequate support to offer technology-relevant training.
- **Attract and retain academics:** Improve conditions of service, support and packages to attract, retain and appoint additional academics.
- **Teaching methods:** Apply the latest methods and technology for teaching, and train academics in 21st century approaches to teaching.
- **Academic development:** Provide funding for lecturer post-graduate development and facilitate opportunities for academics to gain experience in industry.

Graduate training

- **Develop programmes:** The EIZ to develop national graduate training guidelines to ensure graduates achieve the level of competence required by industry and for professional registration.
- **Private sector incentives:** Offer incentives for private sector companies to develop graduates.
- **Public sector support:** Ensure that public sector structures take on and train graduates and that they are absorbed and developed through the ranks.
- **Institutional support:** Institutionalise graduate training in all organisations by setting KPIs for experienced staff to act as supervisors and mentors.
- **Project support:** Make graduate training a requirement of all public sector projects and ensure that the progress of graduates is monitored, and penalties are imposed for non-compliance.

Registration of engineering professionals

- **Registration:** Encourage the registration of all engineering practitioners with the EngRB.

Continuing professional development

- **CPD:** Support the participation of engineering practitioners in CPD activities.
- **Validation:** Validate short courses and skills programmes for a specified period only to ensure that training remains up to date and relevant.
- **Post-graduate studies:** Provide post-graduate bursaries to develop specialists.

- **Develop managers and leaders:** Continue investing in graduates after professional registration to grow management and leadership capabilities.

Registration of service providers

- **Legislation:** Update the Act to:
  - Ensure that there are requirements for consultants and contractors to train graduates, artisans and other construction-related skills.
  - Ensure that international consultants provide all calculations, drawings, operating manuals and other reference material in English.
  - Ensure that local consultants, along with the client, check that design proposals address local needs and customs and that design calculations comply with national codes and standards.
- **Compliance:** Monitor quality and use of local labour, plant and materials as required by the Act and ensure that penalties are imposed for poor performance or non-compliance.
- **Zambianisation**: In line with the Zambianisation policy, ensure that foreign service providers develop local understudies to take over from expatriate experts on completion of their contracts.

Public sector

- **Economic infrastructure:** Invest in the development of economic infrastructure such as electricity, roads, rail, ports and airports, and address the supply of water services.
- **Maintenance:** Invest in maintenance to preserve new infrastructure and prevent further deterioration of existing infrastructure.
- **Tariffs and payment:** Review and increase tariffs where appropriate, enhance domestic revenue collection and demand management to fund development.
- **Technical capacity:** Reprioritise budgets to build technical capacity, ensure that salaries are competitive and develop succession plans to make the public sector an employer of choice.
- **Technical decision-makers:** Appoint engineering professionals in senior decision-making posts.

Industry-wide collaboration

- **Advisory team:** Set up an engineering advisory team, recognised by government, to advise on and endorse infrastructure development proposals, tertiary curricula and graduate training programmes.
- **Collaboration:** Encourage all professional bodies to work together to share knowledge, exchange best practice and ensure coordinated planning of industry support initiatives.

ACKNOWLEDGEMENTS

The detailed picture presented would not have been possible without the support of many associations, government departments and local professionals. A special thank you to Eng. Suzanne Rattray for many contacts and insights and to Eng. Newton Zulu, Eng. Kabwe Musondo and the secretarial staff of the EIZ for providing contacts and organising meetings. Thank you to Eng. Elite M'hone for initiating a survey in the mining sector which offered great insight, to Eng. Malenga Musondo for gathering outstanding information, to Eng. Charity Kapatamoyo Chola and the team at ZESCO for detailed input and to all other departments and organisations who provided data. Last but not least, to Dr Evaristo Musonda for providing higher education data and insights.

SOURCES OF INFORMATION

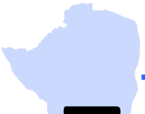
Data and information were gathered during an EIZ workshop in 2018, interviews, telephone conversations and via emails. SADC reports, master plans and strategies as listed under *Plans and Strategies,* and many standard international sets of data as listed in Chapter 5, *Research Approach,* were also consulted. Further information was gathered from news articles, from Labour Force Surveys, and from sector profiles on *Iron and steel*; *Infrastructure*; *Manufacturing*; and *Wood and wood processing*, published by the ZDA. Comprehensive documents focusing on specific issues in Zambia as listed below were invaluable sources of information.

International Labour Office (ILO). 2015. *Good working conditions, good business? An analysis of Zambia's building construction market system*. Geneva: ILO.

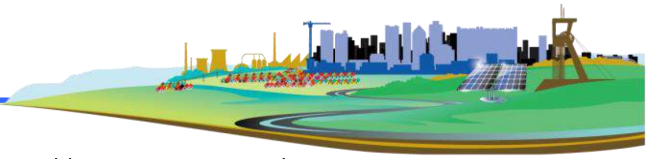
International Council on Mining and Metals (ICMM) & Chamber of Mines of Zambia (CMZ). 2014. *Mining: Partnerships for Development. Enhancing mining's contribution to the Zambian economy and society.* London: ICMM.

Ministry of Trade and Industry (Zambia). 2012. *Industry Strategy for Engineering Products*. Lusaka.

United Nations Development Programme (UNDP). 2016. *Zambia Human Development Report*. UNDP.



ZIMBABWE



ZIMBABWE is a landlocked country bordered by South Africa to the south, Botswana to the west and south-west, Zambia to the north-west, and Mozambique to the east.

Agricultural products and minerals were the main exports in 2017. Zimbabwe is the largest grower of tobacco in Africa and the sixth-largest in the world, making tobacco its leading agricultural export and an important earner of foreign currency. Tourism is estimated to account for about 10% of GDP and is important for generating foreign exchange.

More than 21% of Zimbabweans live below the international and 72.3% live below the national poverty line. Unemployment is widespread. These challenges are exacerbated by the shrinking economy and periods of hyperinflation. In 2017, the HIV/AIDS prevalence rate was at an estimated 9% and was the fifth highest in the world.

The capital city, Harare, is the country's most populous and important city, as it is a major industrial and urban centre. Due to urbanisation without adequate job opportunities, almost 47% of people living in urban areas in Zimbabwe are classified as poor.

THE ECONOMY

Once dubbed 'the breadbasket of the region', Zimbabwe used to produce millions of tons of grain and horticultural products, and was able to feed its own population, the region and, to some extent, other parts of the world. The country has regressed dramatically since the late 1990s as the result of policy changes which affected land ownership, the move to nationalise many companies, unsustainable government borrowings, looting of the fiscus and the associated loss of appetite of private and foreign investors.

Manufacturing, once a key driver of economic growth, contributing about 24% to the GDP in 2009, had declined drastically to 11.3% by 2015 and was predicted to drop further in 2018 due to shortages of foreign currency.

The country still has the potential, but without enabling legislation and substantial investment, engineering capacity will have limited opportunities to assist it to reclaim its former glory.

The technocratic cabinet appointed by President Mnangagwa after the elections in mid-2018 is aimed at driving reforms. Suggestions to scrap the controversial 'indigenisation' laws and measures to address economic policy, currency reforms and a reduction in public spending are being considered.

PLANS AND STRATEGIES

Zimbabwe has many plans and Acts governing the delivery of infrastructure, which, if implemented, would see substantial development. Notably:

- **Vision 2020** which aims for Zimbabwe to be a democratic, prosperous and egalitarian nation with a high quality of life by 2020. Vision 2020 has, however, been discarded due to the poor performance of the country and Vision 2030 is being developed to initiate radical economic

Table 1 : Zimbabwe metrics

Population	
Total	14 516 000
Urban	33%
Rural	67%
Poverty, HIV, Unemployment	
Below the international poverty line	21.4%
HIV-positive	9.0%
Unemployment	11.3%
Human Development Index	0.509
Electricity	
Production kWh	6.8bn
Consumption kWh	7.1bn
Airports and Ports	
Airports	196
- Paved	17
- Unpaved	179
Kilometres of Services	
Roads	97 267
- Paved	18 481
- Unpaved	78 786
Rail	3 427
Oil and gas pipelines	270
Africa Infrastructure Development Index	24.52
Access to Services	
Access to safe drinking water	76%
- Urban	98%
- Rural	67%
Access to improved sanitation	62%
- Urban	98%
- Rural	48%
Access to electricity	40%
- Urban	80%
- Rural	21%
Telephones	305 720
Mobile phones	12 878 926
Internet users	23%

transformation that will witness the country becoming a middle-income economy by 2030. The vision will be attainable if state enterprises are revived and the country focuses on sectors where it enjoys a comparative advantage, such as agriculture, mining and tourism. A National Development Plan will follow when Vision 2030 has been finalised.

- **National Energy Policy (2012)** with objectives of accelerating economic development, facilitating rural development and promoting small- to medium-scale enterprises.
- **Rural Electrification Act (2002)** aimed at expanding the national electricity grid to rural users.
- **Sustainable Energy for Rural Communities (SE4RC) (2015–2019)** which is an initiative to enhance agricultural productivity through solar technology.
- **Urgent Water Supply and Sanitation Rehabilitation Project (UWSSRP)** aimed at rehabilitating water and sanitation systems in six urban centres, namely Harare, Chitungwiza, Mutare, Masvingo, Kwekwe and Chegutu.
- **Integrated Water Supply and Sanitation Investment Plan** for the Greater Harare metropolitan area which covers the medium- (2020) to long-term (2030) needs of the city.

ENGINEERING ACTIVITIES

Figure 1 shows the contribution of engineering-related economic activities to the country's GDP. The largest sector is agriculture, followed by transport and communication, and then manufacturing. Considering each sector in turn will give a picture of the activities, trends, challenges and opportunities for the engineering profession to contribute to the growth of Zimbabwe.

AGRICULTURE

Agriculture is a key element of Zimbabwe's economy. According to the Ministry of Foreign Affairs, although agriculture contributes only 11 to 14% of GDP, the sector provides employment for some 70% of the population. The main exports are tobacco, cotton and sugar. Since 2000, Zimbabwe's farming areas have undergone a fundamental transformation under the land reform programme and have suffered from poor production due to many factors, including:

- Lack of skills and capital, and shortages of physical resources
- Land tenure insecurity, making farmers reluctant to improve, maintain or repair existing infrastructure
- Inadequate investment in the rehabilitation and development of irrigation systems and in the use of agricultural equipment and machinery
- Excessive flooding and associated soil erosion due to climate change
- Unreliable power supplies and high utility charges and levies
- Lack of market information and poorly developed market infrastructure.

Subsistence farming

Smallholders in communal, resettlement and small-scale commercial areas are essentially subsistence farmers, as they grow just enough to feed their own families. Smallholders tend to use retained seeds and few or no inorganic fertilisers, and receive limited, if any, agricultural extension support. With unreliable energy sources, irrigation is limited.

To move beyond subsistence, farmers require access to markets and facilities to store crops until the post-harvest glut is over. Few smallholders have access to storage facilities or can afford the high transport costs, which have escalated due to the poor

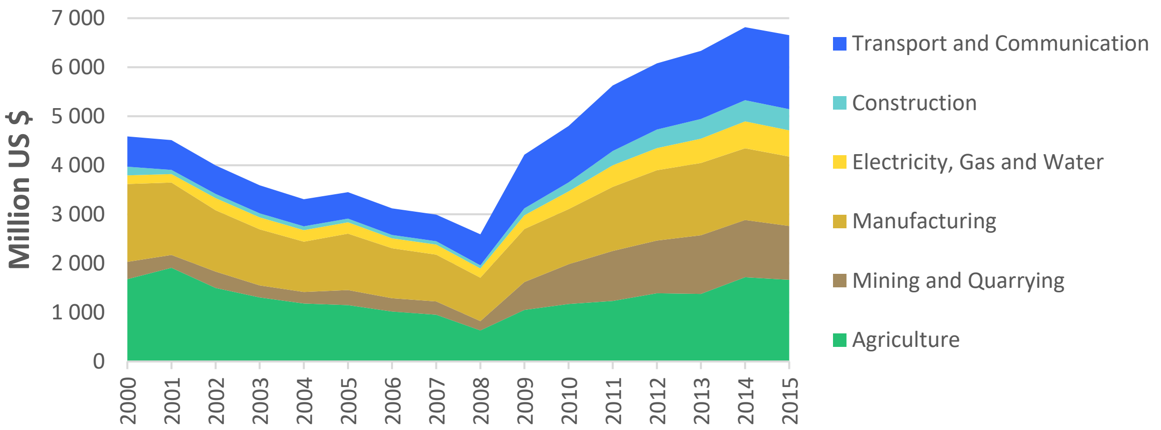


Figure 1: GPD per engineering-related economic activity (53% of the GDP)

condition of the roads. Furthermore, where smallholders do manage to arrange transport, their crops are often damaged in transit due to the poor quality of the ride. With lack of road maintenance, even walking to the nearest centres is a problem in some areas as roads and bridges become impassable in the rainy season.

Commercial farming

The major commercial crops are tobacco, cut-flowers, raw sugarcane, cotton, vegetables (for freezing), coffee, fruit and tea. A significant portion of the crops produced commercially is exported, while crops produced in the communal areas are consumed locally. Cotton is one of the major crops produced for commercial purposes on both communal and commercial lands.

In the NEPAD framework, the Comprehensive Africa Agriculture Development Programme (CAADP) called upon countries to commit 10% of their national budgets to developing the agricultural sector by 2015. Engineering capacity is key to many developments required, including:

- Expansion and rehabilitation of irrigation systems
- Redevelopment of roads and bridges, and expansion of the electrical and telecommunications networks
- Development of machinery and equipment and post-harvest handling facilities.

The above suggests that much attention needs to be given to developing a new cohort of agricultural, civil, electrical and mechanical engineering practitioners, able to support the growth of the sector.

Forestry

Some 60% of the country's land area is under various woodlands, compared with 27% under cultivation. The heaviest concentrations of indigenous woodlands occur in the gazetted state forests, national parks, the Eastern Highlands and large-scale commercial farms. About 70% of the country's population depend on forests for firewood, construction timber, food and fodder.

Deforestation is a major concern, driven by the growth of illegal settlements, seasonal fires, mismanagement and ineffective timber-replanting programmes.

MINING AND QUARRYING

Zimbabwe has abundant natural resources, including gold, coal, iron ore, chromium ore, vanadium, asbestos, nickel, copper, lithium, tin, platinum group metals and diamonds.
Zimbabwe's reserves are such that mining could be a substantially larger contributor to the GDP. However, over and above the difficulties in raising capital and the high royalties payable, the use of antiquated and inefficient equipment, power outages, high tariffs, deteriorating rail transport and road conditions, and the shortage of technical skills are affecting production and the viability of many operations. Illicit diamond sales of many billions of dollars each year also reduce the contribution of mining to the GDP.

A comprehensive survey undertaken in 2007 stated that mining companies were said to require an additional 47 mining engineers, 30 metallurgical engineers, 28 geologists and some 445 technicians, among other skilled personnel. Government was said to need 406 people to fill technical mining posts, 144 civil engineers and 68 survey engineers, among others. As a result, from an exploration point of view, Zimbabwe is said to be several years behind countries with similar geological environments, such as Canada. Until such time as policies and tariffs are reviewed, and funding and economic infrastructure are available, the rich mineral reserves will do little to grow the economy.

Despite the poor conditions and the threat of nationalisation, Zimplats, the country's largest platinum mining company, and Metallon Corporation, the largest gold mining company, have continued to grow, the latter planning to increase its annual production to 500 000 ounces by 2019. Zimplats is planning a new platinum mine which will triple its output and allow the company to replace production from the Rukodzi and Ngwarati mines once they are depleted. The first mining will take place in early 2021 and is expected to reach full production of 2.2 million tons per year in 2025.

MANUFACTURING

Manufacturing in Zimbabwe has declined over the years due to high inflation, shortage of foreign exchange and fuel, inadequate and costly services, such as power and water, inefficient transport and a shortage of skilled labour as a result of the brain drain.

Historically, the country's 'bread basket' status was secured by intensive commercial farming which supported the agro-based industry. By 2009 the contribution of food, beverages and tobacco to manufacturing had fallen to below 30%, as seen in Figure 2.

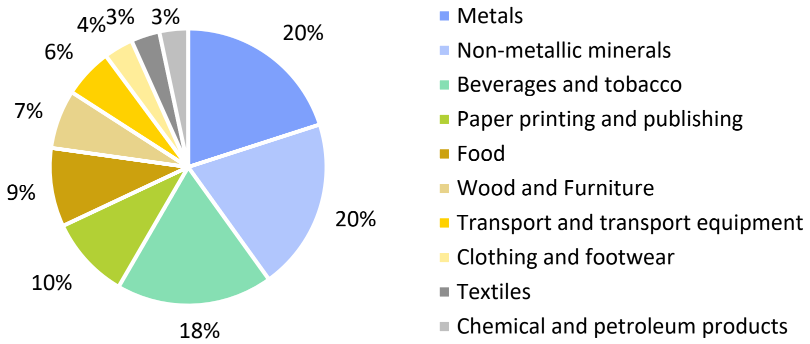


Figure 2: Manufacturing output by subsector in 2010
(Ruzivo Trust. Manufacturing Sector Factsheet)

Zimbabwe exports most of its raw material, losing value and jobs to foreign countries. Large manufacturing firms are generally foreign-owned, while small and medium enterprises are largely locally owned. To support the growth of micro, small and medium enterprises in the manufacturing sector, consideration needs to be given to resolving unfair competition from cheap imports.

Looking at activities in each sector will give a sense of the engineering capacity requirements.

Food, beverages and tobacco products

Beverage production in Zimbabwe covers the range of soft drinks, largely manufactured under licence, juices, alcohol, mostly produced by subsidiaries of international companies, and the production of traditional beer. Production has been limited by a variety of factors, including shortages of beverage and beer packaging (Crowns), lids, carbon dioxide, maize and coal –the industry generally uses coal to fuel its production processes. A manufacturing survey carried out by the Confederation of Zimbabwe Industries (CZI) showed that manufacturing had declined year on year in the 2000s, falling by 28% in 2007 alone. To protect production in the brewing industry, breweries have taken to offering technical advice and assisting with monitoring crops in the field, from planting to harvesting.

Tea and coffee are processed in bulk form for sale, either on the international market or for local and regional packed-tea sales. Tea blending and packaging adds further value and various brands of tea are sold locally and exported to regional markets.

Food processing is regarded as a priority industry due to its enormous impact and industrialisation potential. The Harare Institute of Technology (HIT) carries out extensive research in support of enhancing the processing of grain, cereals, fruit, vegetables, dairy, meat and poultry products. Given the agro-processing potential, Nestlé Zimbabwe has recently expanded their cereal and dairy plants.

British American Tobacco (BAT) has dominated the tobacco market and in 2016 accounted for 86% of the local market share, based on excise duty contributions. Its global brand, Dunhill, continues to be in demand and grew by 7.2% compared with 2015. Although there are several tobacco manufacturers in Zimbabwe, Chinese and South African investors are also looking to set up plants.

Textiles, clothing and leather

Textiles and clothing are key manufacturing subsectors in Zimbabwe. They consist of three components: production and ginning of cotton; transformation of lint into yarn and fabric; and conversion of fabric and yarn into garments.

Engineering skills would play a role in step two, but production has been falling over a number of years, due to competition from cheap imports, low productivity, antiquated machinery, the closure of training facilities, lack of investment and government support, etc. and, coupled with infrastructure challenges such power blackouts and high electricity tariffs, many textile mills and plants have closed.

A range of leather goods, including shoes, are produced locally and tanned leather is exported. In 2011, two million pairs of shoes were produced, but the number has since dropped.

Timber, pulp, paper and packaging

Zimbabwe's natural forests generate a wide range of timber and non-timber products and services. The products include fuelwood for charcoal making, sawn timber and pulpwood, building materials, wood for small artisanal crafts, bark for rope and gum, among others. As a result, there are many sawmills, pulp, paper and packaging plants, and furniture manufacturing is one of the established subsectors.

Plastics, chemicals and other non-metallic mineral products

The plastics industry, which produces pipes, polystyrene, films, household goods, furniture, packaging, bottles and many other products, is under pressure due to tariffs being applied to the importation of raw materials. In 2015, over 30% of the companies were operating below 20% capacity utilisation. The CZI reported that 10 companies in the plastics sector closed in 2014 and eight were under judicial management.

Zimbabwe's beverages and bottling firms are building a US$1 million PET recycling plant to address the disposal of bottles and other PET items.

The chemical industry offers a range of products, including fertilisers, pesticides, paints and varnishes, pharmaceuticals, soaps and cleansing products, perfumes and cosmetics. The fertiliser industry accounts for 32% of chemical supplies manufactured locally, while the balance are imported. The industry is faced with numerous challenges, including outdated technology, erratic supplies of electricity, fuel, coal and water, and dilapidated infrastructure.

Zimbabwe has four cement manufacturing companies which in total produce around 1.5 million tons per year. Local consumption is about 1.14 million tons and the balance is exported in the region.

Pharmaceuticals

The pharmaceutical sector is second to South Africa in the SADC region, producing more than 65% of the Essential Drugs List of Zimbabwe and about 15% of the Special Essential Drugs List. Sadly, a lack of credit lines has greatly reduced the industry's ability to participate meaningfully in the export market. Since the sector employs more than 1 000 people in some nine companies, the government has stepped in to protect local producers by placing import controls on 23 pharmaceutical medicines, covering a range of painkiller and antibiotic tablets, capsules and suspensions, among others.

Metal industries, machinery and equipment

The metals industry involves a range of beneficiation activities, including upstream operations such as smelting, recycling and refining, and downstream activities such as processing, fabrication and machine/equipment building and assembly. Production has been hampered by the lack of funding for power, rail and infrastructure development. The failure to get NewZim Steel operational after its long closure is a major challenge as companies in the sector relied on its predecessor, Zimbabwe Iron and Steel Company (ZISCO), for raw materials.

Zimbabwe's engineering and metals sector has the potential to generate US$14 billion per year if recapitalised, according to the Zimbabwe Economic Policy Analysis Research Unit (ZEPARU). ZEPARU notes that with sound policies, a sound business operating environment, recapitalisation and driving of exports, iron and steel production alone has the potential to turn the trade deficit into a gain. Should such a change take place, a drastic increase in the number of engineering practitioners would be required.

ELECTRICITY, GAS AND WATER

Electricity

To operate efficiently, businesses and factories need electricity supplies that are free of interruptions. As seen in the previous section, erratic electricity supply has crippled the economy. Zimbabwe has huge energy potential, but many existing plants have been closed due to disrepair, or coal shortages, and no new plants have been built since 1988. The ageing plants struggle to cope with increasing demand – generating just over 1 000 MW against a peak demand of 2 200 MW, leaving households, mines and industries to endure hours of rolling power outages.

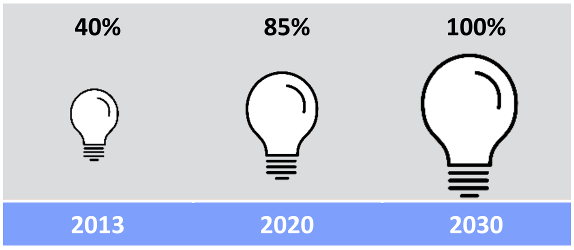


Figure 3: Target dates for access to electricity

In 2013, only 40% of the population had access to electricity, made up of 80% of the urban population and 21% of the rural population. On average, only 12% of connected households have a regular supply. Small-scale power generators are used all over the country to ease the power situation as the cost of rural electrification through grid extension is high due to the scattered nature of settlements.

The energy sector is governed by the Ministry of Energy and Power Development which has set the target of achieving universal access to sustainable energy by 2030. The Ministry has set up a delivery structure made up of the Zimbabwe Electricity Supply Authority (ZESA) and its subsidiaries, the energy-generating company Zimbabwe Power

Company (ZPC) and the Zimbabwe Electricity Transmission and Distribution Company (ZETDC), to generate, transmit and distribute electricity.

Generation

ZPC operates four coal-fired power stations, Hwange, Bulawayo, Munyati and Harare thermal stations, and one hydropower station, the Kariba South Power Station. Working towards universal access, plans are in place to boost the electrification rate to 85% by 2020. To achieve this target, ZESA plans several projects, as shown in Table 2.

Transmission

Increased generation will require a significant increase in transmission to reach the many potential consumers. Plans were in place to start construction of a 1 000 km power line in 2018. This will be done in phases. First the Orange Grove(Mozambique)to-Triangle line, followed by the Triangle-to-Njelele line in South Africa. In partnership with stakeholders from Mozambique and South Africa, Zimbabwe is planning to become a regional power hub by 2021.

Oil and gas

Zimbabwe does not have any indigenous sources of oil and natural gas and depends on imports for liquid fuel.

Water and sanitation

Zimbabwe has limited water resources and largely depends on surface storage for its water needs. In 2014, almost 76% of the population had access to safe drinking water, made up of 98% of the urban population and 67.3% of the rural population, and aimed to achieve 80% by 2018.

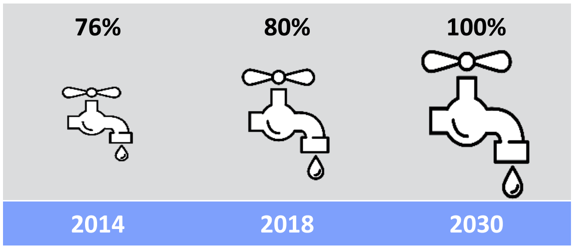


Figure 4: Target dates for access to safe drinking water

In 2014, only 62% of the population had access to improved sanitation facilities, made up of 98% of the urban population, and 67% of the rural population. Many households do not have any type of toilet facility, with 48% of the rural population practising open defecation. The country has committed to achieve the SDGs by 2030.

In urban centres most of the water supply comes from piped water. In rural areas, Zimbabweans rely predominantly on wells and boreholes that tap into the groundwater supply. Water supply and sanitation systems in many urban and rural areas have deteriorated and water-dependent businesses have been adversely affected. Sewerage systems have experienced large-scale blockages, water treatment plants are dysfunctional and lack chemicals, while many distribution systems have fallen into disrepair. The erratic electricity supply has compounded the problem of operating the water supply and sewerage systems.

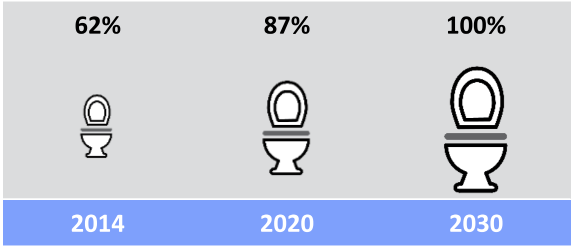


Figure 5: Target dates for access to improved sanitation

Harare has a water reticulation system built to serve 367 000 people, but now attempts to provide Harare's population of three million with potable water. In Harare, 40% of residences have access to clean and safe drinking water daily, while some parts of Harare have not had water supplies for up to five years. Local authorities are faced with financial challenges to refurbish ageing water reticulation systems, resulting in erratic water supplies to critical operations, including industry, and more than 60% of the hand pumps used in rural areas require refurbishment.

The Ministry of Environment, Water and Climate (MoEWC) governs the water sector. The Ministry has set up the Zimbabwe National Water Authority (ZINWA) which is responsible for bulk water supply to urban local authorities, industries and mines, and for agriculture. ZINWA supplies water and sanitation services in some areas, on behalf of the local authorities that do not have capacity to do so. Under the ZINWA Act, No. 11 of 1998, the Authority is also mandated to provide technical assistance to local authorities in the planning, development and management of water services. ZINWA has seven suboffices which are based in the seven hydrological catchments in Zimbabwe.

ZINWA estimates that US$500 million is required to rehabilitate water infrastructure countrywide. The Action Plan for Water Resource Management (2011–2020) includes a major programme to support the storage and transport of water resources to meet current and future demand and to provide inhabitants with access to improved sanitation facilities by 2020.

TRANSPORT AND COMMUNICATION

The Ministry of Transport, Communication and Infrastructural Development is responsible for all aspects related to the management of transport, communications, and meteorological and seismological infrastructure and services. As Zimbabwe is a landlocked country, the transport modes that serve the country's economy are roads, railways and aviation.

Roads

There are almost 98 000 km of classified roads, 18 481 km of which are paved. About 5% are classified as primary roads which link Zimbabwe with its neighbours, and 14% are secondary roads linking the economic centres within the country.

The Zimbabwe National Roads Administration (ZINARA) was set up under the Ministry to secure funding for the maintenance of the country's roads through fixing and collecting road user charges, the fuel levy and any other revenue of the Road Fund. ZINARA allocates and disburses funds to urban and district road authorities and assists them to prepare road maintenance plans, approves the plans and monitors progress.

Only 25% of the road network is in good condition, with an estimated US$5.5 billion required for maintenance and rehabilitation. Not only is rehabilitation necessary, but the addition of new capacity is also required to meet existing and future demand. The rehabilitation and maintenance of major trunk roads commenced in 2009 and is ongoing. Funding for rural roads is the primary responsibility of the government, while other major roads will largely be developed through Public-Private Partnership (PPPs).

Disclaimer:
Aurecon gives no warranty of any kind, expressed or implied, with regard to the map or data whether for its reliability, accuracy or completeness and shall not be held liable in any event for any loss or damage in connection with or arising out of the use of this data or map. The Client accepts all inherent limitations of the maps and data, including the fact that the maps and data are dynamic and in a constant state of maintenance, correction and revision. The data and map remain the sole property of the CLIENT and may be used for purposes of this Project with the prior written approval from the CLIENT. aurecon

Figure 7: Transport corridors

Figure 6: Victoria Falls approach road, rail and bridge connecting Zambia and Zimbabwe
(Photographer: Victoria Brennan)

The 897 km Beitbridge to Chirundu highway, which links Zimbabwe to South Africa and Zambia, requires a complete upgrade to become a dual carriageway road each way. The project is being handled as a 25-year concession. The major construction work was due to commence in the second half of 2017.

Rail

The National Railways of Zimbabwe (NRZ) was established to provide, operate and maintain an efficient system of public transportation of goods and passengers by rail. The NRZ operates about 3 427 km of railway lines, all of 1 067 mm gauge, providing passenger and freight services. The gauge is standard for all of southern Africa.

The rail network is essential for trade. It connects Zimbabwe with all its neighbours, major mining areas, heavy industrial centres and major agricultural collection centres, and provides much of the transport of mineral exports from the region to seaports in South Africa.

Neglect of maintenance, lack of spare parts and overdue replacement of equipment have led to a situation where only part of the network is in good condition. These challenges, coupled erratic supply of power, have led to reduced service. Goods transported on the network declined from 18 million tons in 1998 to 2 million tons in 2010.

In recognition of the challenges, various upgrades and developments have been planned, including the upgrade of rail infrastructure between Bulawayo and Beitbridge through foreign investment in the Beitbridge–Bulawayo Railway (BBR) company.

Another ambitious plan agreed to by Botswana, Mozambique and Zimbabwe is the construction of a regional railway line to link Francistown in Botswana to the Mozambique Port of Techobanine through Bulawayo in Zimbabwe. Once completed, the port Techobanine Inter-Regional Heavy Haul Railway Project would facilitate inter-regional trade through movement of up to 12 million tons of goods per year.

Airports

The Civil Aviation Authority of Zimbabwe (CAAZ) was established to develop civil aviation and promote its safe, regular and efficient use inside and outside Zimbabwe. Plans are being considered to build a new Kariba Airport to increase tourism opportunities. The current airport cannot be upgraded as a gorge and existing power lines restrict the capacity for growth. The Kariba Municipality has made land available. Plans are also afoot to develop new airports in Beitbridge and Mutare. Additional short-haul aircraft will eventually be acquired to allow tourists to criss-cross the country.

To address the backlog in the transport sector, it is recognised that it will be necessary to increase the budgetary support for maintenance progressively over the next 30 years and to promote the retooling of the rail and air transport operators.

Communications

Fixed-line services are offered in Zimbabwe by TelOne, which offers voice and data services in the form of xDSL broadband. Voice services form 50.8% of their revenue, whereas data services account for 36.5%.

Mobile network operators are the principal providers of basic telecom services. Mobile telephony has a 79.7% penetration rate, with Econet holding 51.7% of the market, while internet penetration was approximately 23% of the population as of 2016. With basic telecoms being hampered by poor physical infrastructure and lack of maintenance, mobile telephony has grown to fill the role traditionally filled by land-based telecommunications, so that 97.7% of internet connections use mobile technologies whereas fixed line telephone services only serve 2% of the population. The mobile telephone operators are thus the *de facto* internet service providers. Of the 6.8 million mobile data users, 641 152 access the internet using LTE technology.

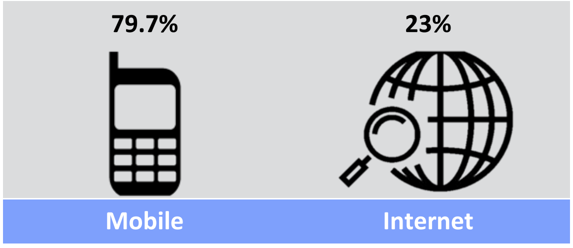


Figure 8: Percentage of population connected to services

The country's link to the SEACOM and EASSy submarine fibre optic cables is in Mutare, which connects to Maputo in Mozambique. Liquid Telecom is the largest provider of internet bandwidth in the country, holding 78.7% of the market share in 2017. Total international incoming bandwidth capacity was rated at 101 625 Mbps in 2017, with the amount of international incoming bandwidth used being 48 188 Mbps, which will allow a further 51% growth.

Liquid Telecom is the largest data, voice and IP provider in Zimbabwe, supplying wholesale fibre optic, satellite and international carrier services to telecommunications operators. Liquid Telecom was the first in Zimbabwe to introduce Fibre To The Home (FTTH), connecting households across the country onto the high-speed fibre network. They also provide the backbone for rural and remote mobile data connections.

To address the training needs in the telecommunications sector, TelOne has opened the TelOne Centre for Learning (TCFL), which offers diplomas in a range of disciplines, including software engineering.

CONSTRUCTION

Construction is important in any country due to its ability to create jobs and develop skills. However, from employing 20% of the labour force in 1996, employment in this sector was reported to be down to 5% in 2013.

Lack of capital inflows and of major national development projects were some of the constraints cited by stakeholders in the construction industry. Construction delivery has been increasingly hampered by the failing road and transport network, and by erratic and costly electricity supplies. In the 2017 national budget, only US$520 million was allocated for capital expenditure and in 2018 only US$129 million was allocated.

ZIMBABWE

Most of the skilled and semi-skilled manpower in the sector has left the country. As a result, large projects are generally taken up by foreign contractors, which are able to raise capital, and to provide skills and state-of-the-art technology and equipment. The AfDB Report on Infrastructure and Growth in Zimbabwe (2011) estimated that the country would need about US$14.2 billion at 2009 constant prices to upgrade existing infrastructure and create new capacity from 2011 to 2020, but would require private investment. BMI Research has suggested that this figure could be even higher at US$21 billion. However, due to the inability to develop bankable project proposals, considering regulatory, viability, capacity and environmental issues, among others, funding has not materialised.

Local contractors complain of losing the limited number of opportunities there are to foreign contractors who tend to be backed by their national governments and are able to offer low quotes. When appointed, they bring in cheap building materials, pay below the minimum wage and do not abide by the Zimbabwean building and construction laws. The major projects planned are listed in Table 2.

Housing

There are over one million names on the housing waiting lists in urban centres. It is estimated that there are many as 100 000 stands in and around Harare that are not fully serviced with roads, water and reticulated sewerage. Housing development is hampered by lack of funding and the need to address the lack of, or obsolete, infrastructure for water extraction, treatment and transmission; sewerage extraction, treatment and disposal; and traffic congestion, particularly in CBDs.

The Ministry of Local Government, Public Works and National Housing is responsible for providing housing. In response to the challenge of providing expansive infrastructure, the National Housing Delivery Programme (2014–2018) prescribes that 20% of the land allocated for housing should be reserved for the construction of flats. It is suggested that areas near the CBD should be rezoned to reduce travel distances and costs. Although efforts are being considered for urban housing, little is being done to address rural housing. This is resulting in increasing urbanisation, but existing facilities are inadequate to accommodate the movement of people, resulting in poor living conditions.

LOCAL GOVERNMENT

Twenty-eight councils making up local government structures are provided for in the Urban Councils Act, Chapter 29:15 – six city councils, ten municipal councils, eight town councils and four local boards. The city councils are located in urban areas with large populations and diversified economic activities, while the municipal councils cover the suburban regions. Town councils are proclaimed in centres that have grown from service centres in the rural areas to a size sufficient for them to stand alone. Local boards are located in centres with small populations which have the potential to grow into urban centres and require some level of service.

Table 2: Major projects identified, or being planned or under construction

PROJECT		VALUE US$	START YEAR	END YEAR
Energy	Batoka Gorge Hydro Scheme 800 MW (2x400 MW) hydropower; feasibility underway	$2.9bn	2018	2024
	Gairezi River Scheme 300 MW (2x150 MW) hydropower	$110m	2018	2021
	Gokwe North 1 400 MW coal-fired	$1.4bn	Feasibility	
	Hwange Power Station Improvement 920 MW coal-fired	$600m	To be finalised	
	Hwange Power Station Extension 600 MW (2x300 MW) coal-fired	$1.5bn	2017	2021
	Kariba South Extension 300 MW (2x150 MW) hydropower	$355m	2015	2018
	Lupane Coalbed 300 MW gas-fired; feasibility not commenced	$580m	2019	2022
	ZPC 300 MW (3x100 MW) solar	$570m	Feasibility	
	Zimbabwe–Mozambique Interconnector	Pre-feasibility		
	Zimbabwe–South Africa Interconnector	Pre-feasibility		
	Zimbabwe–Zambia–Botswana–Namibia Interconnector	$223m	2019	2021
Water	Chirundu Cross-Border Water Supply and Sanitation Project between Zambia and Zimbabwe, including upgrade of treatment facilities	$75m	Feasibility	
Roads	Beitbridge One-Stop Border Post (South Africa–Zimbabwe)	$240m	Seeking finance	
	Harare–Masvingo–Beitbridge Road	$693m	Seeking finance	
	Beitbridge–Bulawayo–Victoria Falls Road	$820m	Seeking finance	
Rail	Techobanine Inter-regional railway project	$600m	Seeking finance	

The engineering responsibilities of local government include the supply of water for domestic, commercial and industrial areas and sanitation services; refuse removal; establishment and maintenance of roads, bridges, drains, parking, street and traffic lighting, and public transport services; firefighting and prevention services; and environmental controls.

They must also maintain and establish amenities, including education institutions, health and recreation facilities, libraries, museums, parks and open space, etc. However, budgets are limited, resulting in limited maintenance taking place and infrastructure being in poor condition. Salaries are also low, making it difficult to retain experienced engineering staff.

EDUCATION, TRAINING AND PROFESSIONAL DEVELOPMENT

Education and training are a vital part of developing engineering capacity. All elements, from teaching appropriate subjects at schools to continuing professional development (CPD), need to be in place to educate, train and ensure that engineering personnel remain abreast of the latest technology, challenges and emerging solutions.

PRIMARY AND SECONDARY EDUCATION

Primary education covers seven years, with emphasis on mathematics, English, Shona/Ndebele and subjects such as science, geography, health, environment and social studies, among others. Zimbabwe is one of the most literate countries in the continent, with a literacy rate of over 92%.

At secondary school, each pupil is expected to take two practical subjects such as woodwork, metalwork and technical graphics to instil positive attitudes towards technical subjects.

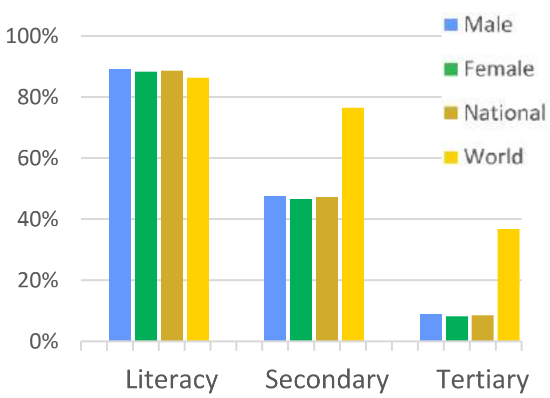


Figure 9: Literacy and enrolment statistics
(UNESCO from 2013 to 2015)

In 2016, Zimbabwe's Ministry of Higher and Tertiary Education, Science and Technology introduced the Science, Engineering, Technology and Innovation Strategy to promote learning in those fields. It was recognised that an enabling regulatory framework is needed to foster PPPs in higher and tertiary education institutions. This resulted in a conscious effort to direct more students towards the STEM disciplines.

TERTIARY EDUCATION

There are 13 universities in Zimbabwe, five of which support technical education as shown in Table 3. Apart from the University of Zimbabwe (UZ), they offer five-year, BEng degrees, one year of which is allocated to industrial attachment, usually after two years. UZ has always offered a four-year degree with no industrial attachment, but will move to offering a five-year degree, including a year in industry. The universities also offer MSc programmes in mechanical, electrical, civil and water engineering, renewable energy, as well as manufacturing systems and operations management. UZ alone has produced more than 1 000 engineers over the years.

The institutes and polytechnics offer national diplomas for the training of technicians, higher national diplomas for technologists, and BTech(Hons) for engineers. The national diploma is a three-year qualification, made up of a two-year national certificate, followed by a third year of study after which a national diploma is awarded.

The major institutions offering engineering qualifications are listed in Table 3, but it is understood that there are other institutions which graduate small numbers each year. Detailed graduation data per discipline, year and gender were not readily available from central sources but had to be gathered from each institution. There was some confusion as to what qualifications were considered to be technician qualifications and it is contended that some of the data listed includes national certificate graduates, which are not part of this study. Where data was not forthcoming, average values from the Ministry were used, and an asterisk (*) is shown where data was estimated during telephone conversations. Due to the uncertainty about the number of technicians graduating, workforce projections have been limited to engineers and technologists in the *Numbers and Needs* section.

Despite several being long-established academic institutions, many challenges have been recognised, including:

ZIMBABWE

- Loss of lecturers at several universities and polytechnics, due to the brain drain. As a result, certain key disciplines cannot be taught or examined adequately because of a shortage of lecturers or examiners, such as in the mining department at UZ. For two years, no students could be taken on due to lack of capacity. Zimplats have since funded a Chair in Mining which has allowed an internationally respected professor from the USA to lead the department. Some universities indicated vacancy levels of up to 50% in 2018.
- Compromised quality of graduates
- Limited levels of interaction between industry and some academic institutions
- Lack research funding and poor coordination among academic and research stakeholders creating counterproductive competition.

The graduation statistics by institution and category are shown in Table 3 and the split by discipline, category and gender is shown in Figure 11.

Due to poor salaries and the brain drain, many lecturers are recent graduates, who have had little or no post-graduation experience and have simply taken academic posts due to a lack of employment opportunities in industry. This affects the quality of graduates and the ability of institutions to develop their research capacity.

Although the curricula have their origins in UK institutions, the lack of capacity and equipment have resulted in a reduction in the content and complexity of subjects being taught. As a result, some engineering degrees do not satisfy the Washington Accord requirements. When Zimbabwean engineers apply to the Engineering Council of South Africa (ECSA) for recognition of foreign qualifications, they are advised at times that their qualifications are equivalent to Sydney Accord standards, and they may apply for registration as professional technologists and not professional engineers. This is extremely disappointing and frustrating for those applicants.

Table 3: Engineering graduations in Zimbabwe in 2015 (unless otherwise noted)

INSTITUTIONS	QUALIFICA-TION	Agricultural	Chemical/ Environmental	Civil	Computer/IT	Electrical, Energy & electronics	Industrial	Mechanical or Mechatronics	Mining & Metallurgy	Textiles
Public institutions										
Bulawayo Polytechnic (part of NUST) (values an average from 2012 to 2018)	ND			183		58		60		
	HND			10		2		4		
Chinhoyi University of Technology (CUT)	BTech (Hons)	15*			67	13	29			
	BEng		4 Env (2017)					26		
Gweru Polytechnic	ND						1	2		
Harare Institute of Technology (HIT)	BTech (Hons)		32			50	23			
Harare Polytechnic	ND			208	86	265		276		
	HND			6	19	32		7		
Kwekwe Polytechnic (part of NUST)	ND			49		9			11	
	HND					17				
Masvingo Polytechnic	ND	26	13	13		72		12		
	HND					5		1		
Mutare Polytechnic	ND			131		10		15		
	HND			23		17		3		
National University of Science & Technology (NUST)	BEng		34	37		44	61			7
University of Zimbabwe (UZ)	BEng	25*		28		36		18	26	
Zimbabwe School of Military Engineering	ND			16 (2017)						
Private institutions										
Midlands State University	BEng		NQ						NQ	
Zimbabwe School of Mines	ND & HND								98 (2017)	
TOTAL										
Engineers (575)		40	70	65	67	143	113	44	26	7
Technologists (176)				39	19	73		15	30	
Technicians (1 576)		26	13	600	86	414	1	365	79	

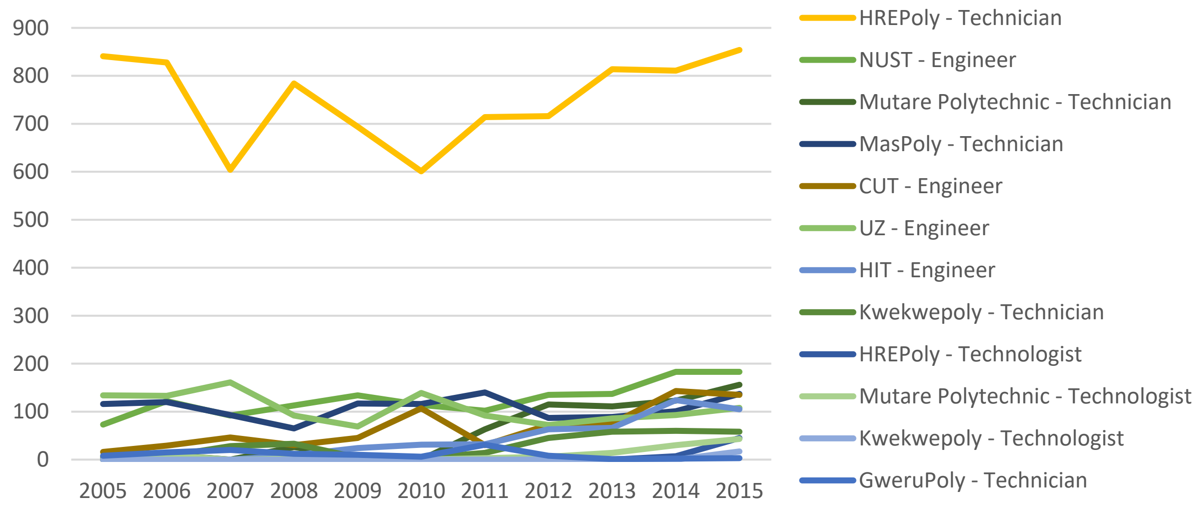


Figure 10: Engineering graduates by institution and category

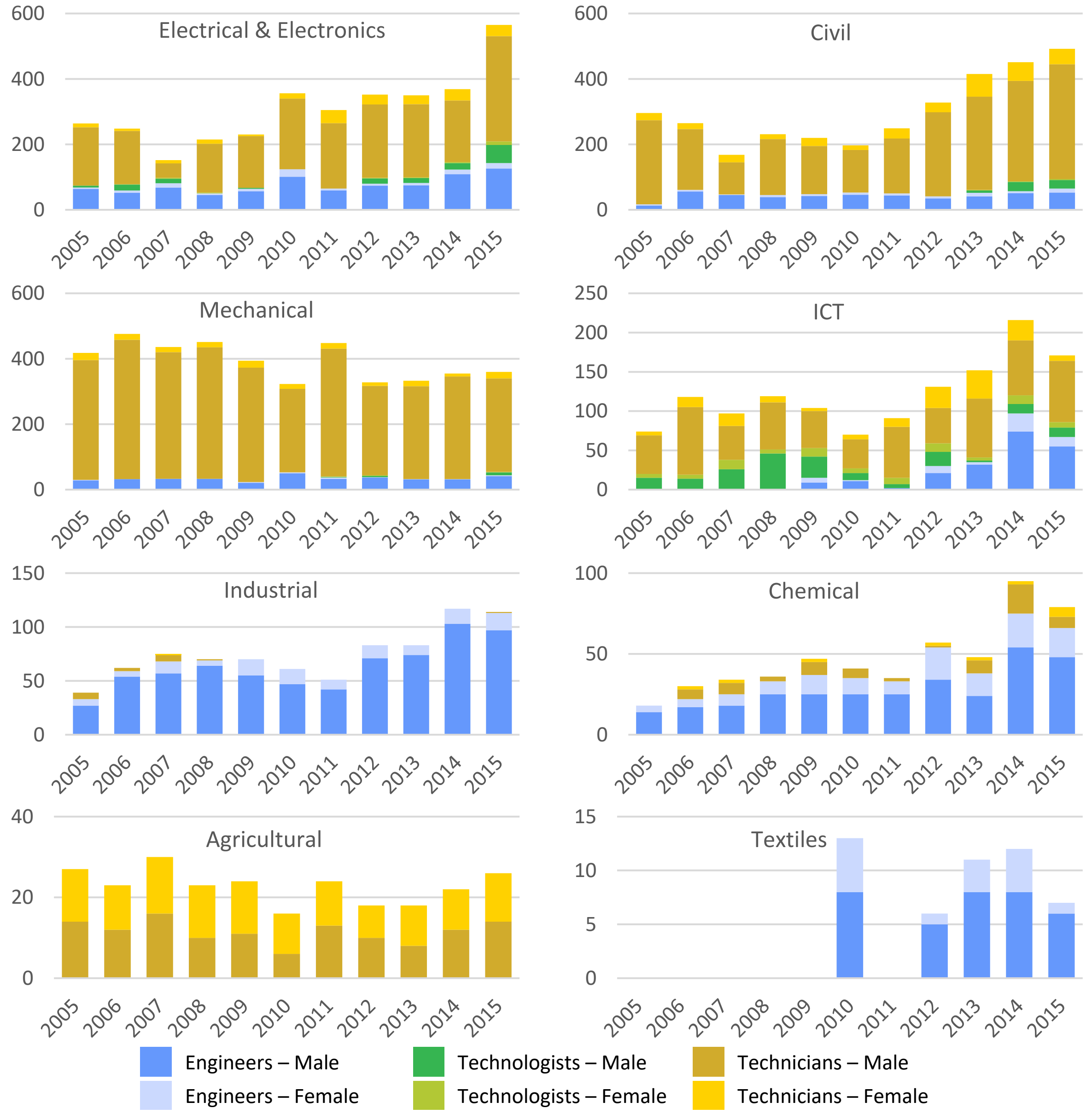


Figure 11: Engineering graduates by discipline, category and gender from selected institutions as per Figure 10

With regard to mining, which is a key economic sector, a report by Prof. Keith Viewing, in 2007, highlighted the drop in the number of technical staff being trained for the industry. His report stressed the shortage of lecturers, the drop in the number of mining engineering graduates and the need to train more technicians. In response, the polytechnics and the School of Mines have added various engineering qualifications and increased enrolment.

Given the current economic conditions, the number graduating exceeds the number who can be absorbed. Zimbabwe is of the opinion that their graduates can be exported to address shortages elsewhere. However, as discussed above, the quality of the graduates is of concern, resulting in large numbers of unemployed graduates. Plans are afoot to deliver more engineering qualifications to boost numbers. This does not make sense and should be reconsidered, unless significant investment is made into the both higher education sector and the development of infrastructure.

Funding under the first phase of the Royal Academy's Higher Education Partnerships for sub-Saharan Africa (HEPSSA) programme was made available in 2015. The University of Zimbabwe elected to use the funds to offer young academics the opportunity to spend time in industry and collaborate with industry to extend the research agenda. Working with NUST, HIT, Chinhoyi and universities from neighbouring states, many industrial attachments have taken place and a project to deliver water to a community offered good practical experience. This has also enabled academics to interact more widely with industry to negotiate industrial attachments for their students, and engage when mentoring and monitoring students during their attachments. Sadly, due to obsolete equipment at the universities, returning students and academics have little opportunity to practise what they learn in industry.

Accreditation

Higher education qualifications are accredited by the Zimbabwe Council for Higher Education (ZimCHE). In the case of engineering qualifications, ZimCHE calls on professional bodies to recommend experts to assess qualifications being submitted for accreditation. ZimCHE is in the process of developing a National Qualifications Framework (NQF) to ensure that articulation is possible from one qualification to the next, as progression has not been possible in the past. The Department of Quality Assurance and Standards accredits diplomas offered by technical and vocational institutions.

Student mobility

In 2015, a total of 27 653 Zimbabwe nationals were studying at South African universities, of whom 16 817 were studying by correspondence through the University of South Africa. A total of 200 engineering students graduated – 89 completing degrees, 64 BTechs and 47 national diplomas.

Eighteen per cent of the membership of the Zimbabwe Institution of Engineers (ZIE) has studied out of the country over the years. A large contingent has studied in China (8.6%), followed by South Africa (3.6%), the UK & Ireland (2.2%), and India (1.1%). Zimbabweans have studied as far afield as Russia, Cuba, the USA, Canada, Australia and New Zealand, and in many of its neighbouring countries.

GRADUATE TRAINING

Once the tertiary education phase is complete, it is necessary for graduates to receive structured training in the workplace, under professional supervision and mentorship, to develop to the level of competence required for professional registration, and to be able to take on work independently. Unfortunately, due to the state of Zimbabwe's economy, employment opportunities are limited. Many graduates find themselves unemployed or move to neighbouring states to seek employment. If Zimbabwe is to grow capacity for the future, structured, funded graduate training needs to be put in place.

PROFESSIONAL REGISTRATION

The Engineering Council of Zimbabwe (ECZ) was set up, through the Engineering Council of Zimbabwe Act, (Act No. 3 of 2008, Chapter 27:22), and Statutory Instrument 153 of 2012, to register engineers and technicians with a view to ensuring that practitioners are competent to perform engineering functions, in the interests of public safety and well-being. Other important roles include accrediting higher education institutions to ensure that the standard of engineering qualifications is upheld, and encouraging manpower development to meet the needs of the country. Registration data is shown in Table 4.

The ECZ is busy developing an update to the Act, which will include the registration of technologists. Existing clauses need to be revisited, such as the current exemption of public sector engineering officials from being professionally registered. While it is accepted that junior posts would not be filled with registered professionals, it is important that senior managers have been assessed by their peers

Table 4: Registration with the ECZ in October 2018

DISCIPLINE	Pr Eng	Pr Tech	Temp Pr Eng	Temp Pr Tech
Aeronautical	1	0	3	0
Agricultural	1	1	4	0
Chemical	21	1	8	2
Civil	391	67	145	42
Electrical/ Electronics	383	122	282	37
Industrial	61	3	46	8
Mechanical	179	28	86	82
Metallurgy	13	5	11	4
Mining	14	6	36	9
Telecoms	17	38	52	18
TOTAL	**1 081**	**271**	**673**	**202**

to have achieved the level of competence expected of senior professionals in government. Mechanisms for Recognition of Prior Learning (RPL) also need to be included in the amendment to accommodate many competent engineers who have worked their way up through the ranks over the years, but did not complete the qualifications that today are considered to be a prerequisite for registration.

VOLUNTARY ASSOCIATIONS AND CONTINUING PROFESSIONAL DEVELOPMENT (CPD)

Once they have been registered, it is a requirement that professionals participate in CPD activities to keep up to date with the latest technologies, trends, legislation, etc. Typically, voluntary associations acting as interest groups deliver training for their members.

The Zimbabwe Institution of Engineers (ZIE), a multi-disciplinary engineering body, initially formed as the Society of Engineers in 1944, has as its purpose to set and maintain standards of engineering competence, promote the advancement of engineering, and facilitate the transfer and dissemination of engineering knowledge.

In response to the requirements for CPD set by the ECZ, the ZIE has taken responsibility for assessing courses, seminars and conferences offered for CPD by providers, and promoting and organising many such events themselves. The ZIE has a range of member categories, including Honorary Fellow, Fellow, Member, Associate Member, Technician, Graduate, Graduate Technician and Student. The ZIE also accommodates Affiliated Organisations. In July 2017, it had a total of 6 304 members, excluding students and organisations.

WOMEN IN ENGINEERING

The percentage of women in engineering in Zimbabwe is lower than in most of the neighbouring states, although there are now female office bearers in the ZIE. Working with *WomEng* and the Royal Academy of Engineering on an initiative funded by the Newton Fund, a programme is underway to develop a *WomEng* Chapter in Zimbabwe. The aim is to attract more women into the profession and support all women in the engineering pipeline, from students entering tertiary education, to workplace orientation for graduates, and leadership development for those with experience needing to further develop their careers.

THE WORKFORCE

The National Statistics data from 2014 suggests that Zimbabwe has some 5 250 engineers and technologists and 2 350 technicians, making the total 7 600. This is slightly higher than the ZIE membership. The ZIE contends that there has been significant 'brain drain' and many of their members no longer work in Zimbabwe, though they hope to return once development commences. The age and gender distribution of ZIE members, which is indicative of mix of engineering practitioners in the workforce, are shown in Figure 12.

THE PRIVATE SECTOR

The main employers in the private sector are consulting, contracting, manufacturing, supplier and mining companies. Lower numbers are employed in small entrepreneurial companies, NGOs, training organisations and other companies where engineering input is required.

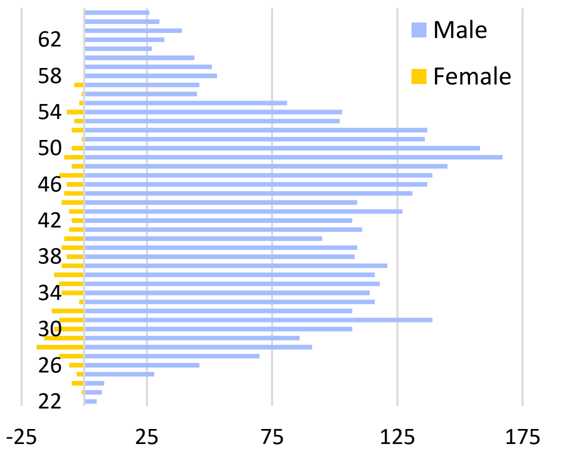


Figure 12: ZIE membership, excluding students, by age and gender in 2017

ZIMBABWE

Consulting

The Zimbabwe Association of Consulting Engineers (ZACE) was formed in 1962 with the prime objective of representing the interests of Consulting Engineers in Zimbabwe. Some 60 consulting engineering companies belonged to ZACE in 2018, categorised to operate in vparious disciplines covering civil, electrical, mechanical and structural engineering, and general. Many companies are branch offices of international or regional consulting organisations, but many local companies have developed over the years and are now well established.

Contracting

In 2014, the Labour Force Survey reported that just over 100 000 people were employed in the construction sector as a whole. This would include consulting engineers, contractors and suppliers. With lack of investment, this number has dropped dramatically in the past few years. Low barriers of entry due to lack of construction regulations mean that the market is saturated and there is heavy competition, including from foreign contractors, especially Chinese. Foreign contractors generally win all large projects as they have significant machinery and equipment, and are able to access capital.

Limited opportunities for capacity development, along with Tender Board Procedures being inconsistent limits the ability of indigenous micro, small and medium construction enterprises to deliver projects. The Construction Industry Federation of Zimbabwe (CIFOZ), in conjunction with the Zimbabwe Building Contractors Association (ZBCA), are pushing for a contractors' Bill in which they are lobbying the government to prioritise project allocation to Zimbabwean companies. CIFOZ is a non-profit organisation which has Professional Members and/or Companies in the following categories:

- Building Contractors: Category H to A
- Civil Engineering Contractors: Category H to A
- Specialist Services/Subcontractors
- Suppliers and Hirers of Earthmoving Equipment
- Associates/Suppliers of Construction Material.

The Zimbabwe Construction Industry Council (ZCIC) is a further grouping which seeks to coordinate views and consider the well-being of all professions in the built environment, including architects, quantity surveyors, consultants and contractors.

Manufacturing

In 2014, the Labour Force Survey reported that just over 250 000 people were employed in the manufacturing sector as a whole. This would include thousands of micro enterprises creating hand-made products. The Industrial Development Corporation of Zimbabwe (IDCZ), a parastatal, was set up to foster economic growth by promoting trade and investment. It has invested in and oversees the development of companies in many key sectors, including chemicals, glass, plastics, agro- and mineral processing, the motor industry and textiles, among others, to develop markets and grow employment opportunities in those sectors.

Various private sector associations represent the interests of manufacturers and the business community, including the CZI. The CZI carries out an annual survey to understand the challenges faced by the industry, which has been in decline for several years. The biggest challenges are cited as low demand (due to reduced spending power as a result of the state of the economy), the financial liquidity crisis and competition from cheap exports. They also mention infrastructure, such as energy cuts and poor rail services, as being constraints to operations.

Mining

According the Labour Force Survey, the mining sector employed 94 000 people in 2014. Research into mining skills in 2016 suggested that while there may be sufficient engineering skills for routine processing work, experienced managers and exploration specialists are generally sourced from the expatriate community. There is a need to ensure that skills transfer takes place to local staff, and that additional management and leadership training is put in place to allow local skills to grow. There was also a concern that higher education and the mining sector did not work together to ensure that the curricula were relevant and that laboratory equipment was up to date.

THE PUBLIC SECTOR

Many engineering practitioners are employed in the public sector and in local government. The departments that employ substantial numbers of engineering practitioners are shown in Table 5.

Due to the weak financial position of the country, neither the engineering capacity nor budgets are adequate to redevelop or expand engineering services. Public servants complained of their heavy workload, difficulty in attracting staff because of very low salaries, and lack of budget for training.

A concern highlighted was the demise of training courses or facilities for road material testers. Neither the laboratory at UZ nor the one at the Ministry is adequately equipped to train testers. Material testing is considered to be inadequate, at times resulting in road materials that are not up to standard being used for road construction. This reduces the lifespan of the road.

Substantial vacancies were reported in some sectors, impeding their ability to deliver services. In many cases, departments rely on subcontractors to carry out their installation and maintenance work. Departments need to ensure that training is given not only to their own staff, but also to subcontractors performing similar duties.

Of concern is the fact that public sector engineering staff have been exempted from registration with the ECZ. Many of the current senior staff are long-serving experienced staff but, in time, the absence of this requirement could well result in inexperienced or incompetent staff being placed in senior positions.

Table 5: Ministries employing engineering practitioners

MINISTRY/STRUCTURE
Ministry of Agriculture, Mechanisation and Irrigation • Agricultural and Rural Development Authority (ARDA) • Cold Storage Company (CSC)
Ministry of Energy and Power Development (MEPD) • Zimbabwe Electricity Supply Authority (ZESA) • Zimbabwe Power Company (ZPC) • Zimbabwe Electricity Transmission and Distribution Company (ZETDC) • Zimbabwe Energy Regulatory Authority (ZERA)
Ministry of Environment, Water and Climate • Zimbabwe National Water Authority (ZINWA)
Ministry of Health and Child Care
Ministry of Higher and Tertiary Education, Science and Technology Development • Zimbabwe Council for Higher Education (ZIMCHE) • Department of Quality Assurance and Standards
Ministry of Industry and Commerce • Zimbabwe Iron and Steel Company (NewZim Steel) • Industrial Development Corporation of Zimbabwe (IDCZ) • Zimbabwe Investment Authority (ZIA)
Ministry of Information Communication Technology, Postal and Courier Services • TelOne
Ministry of Local Government, Public Works and National Housing • Department of Local Government • Department of Public Works
Ministry of Mines and Mining Development • Zimbabwe Mining Development Corporation (ZMDC)
Ministry of Transport and Infrastructural Development • Civil Aviation Authority of Zimbabwe (CAAZ) • National Railways of Zimbabwe (NRZ) • Zimbabwe National Roads Administration (ZINARA) • Air Zimbabwe

Recognising the need to rebuild skills in Zimbabwe, the development of a national skills plan has been initiated. It will be important for the engineering profession to be intimately involved in this process.

MIGRATION TRENDS

Analysis of the United Nations Population Division statistics for 2015 shows a net loss of professionals from Zimbabwe. Forty-eight per cent of professional emigrants moved to South Africa, 20% to the UK and Northern Ireland, and 9% to the USA. Emigrations have been attributed to socio-economic and political unrest, natural crises such as droughts, and poor social, macro-economic policies (including land reform policies and limited freedom of speech and democracy).

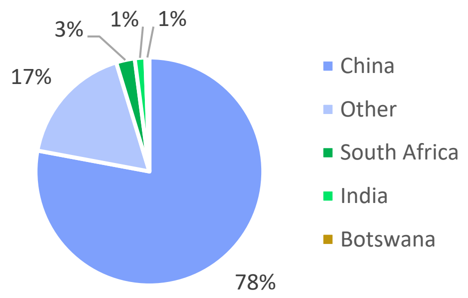


Figure 13: Nationalities of foreign engineering practitioners registered with the ECZ

These statistics relate to those who have officially immigrated or emigrated. There is, however, a constant flow of engineering skills as contracts are awarded to international contractors, who enter on a temporary basis. Chinese engineering staff made up the largest number of foreign practitioners registered with the ECZ in 2018, as can be seen in Figure 13. They represented 30% of all those registered, of whom 78% were engineers and 22% technicians. Only 1 395 Zimbabweans in total were registered.

ENGINEERING NUMBERS AND NEEDS

It is clear that there is huge potential to develop many valuable resources in Zimbabwe and see the country return to prosperity. This will require a substantial team of engineering personnel. However, simply sending more students to study engineering when no investment, development or graduate training is taking place will not address the need.

Once investors return to the country, experienced engineers will be required to conceptualise and specify projects and monitor progress. Further capacity will be required on the delivery side with regard to contracting, manufacturing and mining. Graduates should be harnessed in all these developments, paired with more experienced staff, to develop as young professionals able to plan, deliver and operate infrastructure.

Table 6 shows the number in industry, based on the 2014 National Statistics, and the number who graduated in 2015.

Table 6: Numbers graduating and in employment

CATEGORY	GRADU-ATING	2014 - IN INDUSTRY	%
Engineers and technologists	751	5 250	14.3%
Technicians	1 576	2 350	67.0%

It can be seen that the ratio of technician graduates to technicians in industry is extremely high. This possibly indicates that returns from tertiary institutions with respect to technician graduations included those with national certificates as well as national diplomas, but clarification was not received. An analysis of the flow of future skills will therefore look only at engineers and technologists. When reviewing the country's needs as part of the skills planning exercise that is underway, the technician numbers and needs will need to be investigated.

Figure 14 shows the current workforce, the losses that will occur over the 18-year period to 2035 due to retirement, mobility and mortality, and the growth in engineering capacity if engineering graduations increase at 2% per year over the period. An allowance is also made for graduates returning from studies in South Africa and elsewhere.

The blue dotted line shows the growth in skills that would be required at the 2017 GDP growth rate of 3.7% and the green dotted line shows the growth based on the 2018–2023 GDP projection of 4.6%. A 70% employment elasticity figure has been used to extrapolate the employment demand.*1

At the projected growth rate of 4.6%, there will be an excess of engineers and technologists graduate. The supply will also exceed the Agenda 2063 growth rates.

The number graduating can only be absorbed if government reprioritises its budgets and invests in infrastructure development and maintenance, and if the private sector is able to attract investment and expand to achieve the industrialisation targets. The number of graduates relative to experienced Zimbabwean staff in the workplace will be high considering the large number of Chinese staff currently being deployed. Rigorous structured programmes will be required to ensure that graduates are adequately trained to become independent professionals.

Should the country continue business as usual and employ only some 5 000 engineers and technologists, there will be thousands of unemployed engineering graduates. This will be

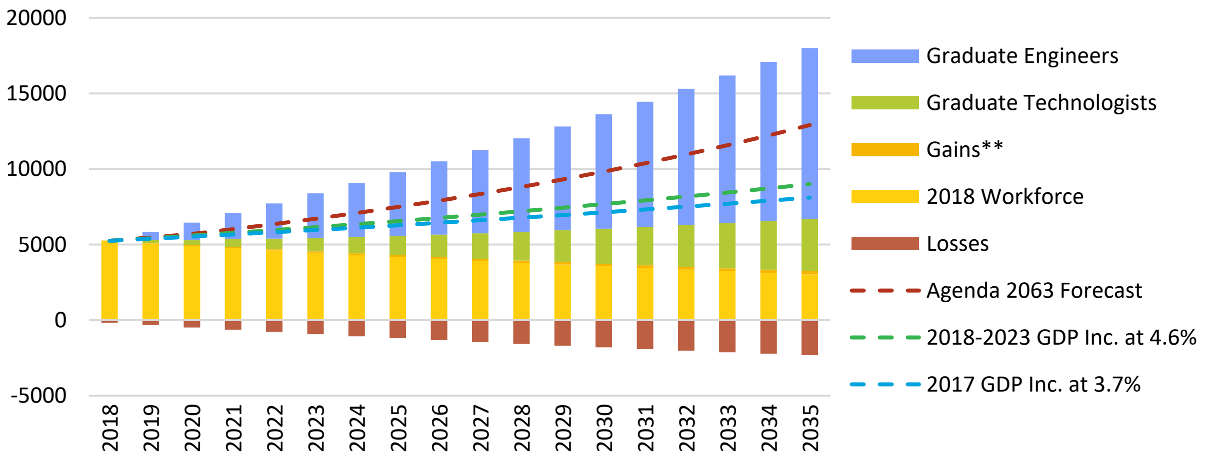


Figure 14: Flow of engineers and technologists in the workplace based on a 2% graduation rate per year

***Excludes international engineering practitioners in the country on short-term contracts and not registered with the ECZ. Those registered with the ECZ are included in the workforce.*

*1 Employment elasticity is a measure of the percentage change in employment associated with a 1% change in economic growth. If the growth is likely to be in agriculture, the percentage could be lower, as growth in that sector generally has to do with productivity gains and not employment, while if the growth is likely to be in high-tech manufacturing, the elasticity factor maybe more than 100%. These considerations will need to be factored into Human Resource Demand Planning.

exacerbated by additional graduates emerging from the new institutions that are being developed or planned. Consolidation is called for and institutions with the capacity and resources to offer quality education should be supported to achieve the standards as defined by the International Engineering Alliance.

Of concern is reference made in various reports of the need to achieve the ratios of OECD levels of engineers to population. Applying a flat ratio across all economies is not appropriate. Many factors affect the numbers required, including the level of expenditure, levels of services delivered, the extent of the infrastructure network, and the level of technology required in the manufacturing sector, among others (refer to Chapter 12, *Numbers and Needs*).

Zimbabwe appears to be educating enough technicians at the moment. The challenge from industry appears to be the content, which does not address the needs in the workplace.

KEY RECOMMENDATIONS

To develop a sound pool of engineering professionals, able to contribute to the well-being of Zimbabwe, the following should be considered:

Schooling

- **Career guidance:** Expand career guidance to attract high-calibre entrants into the engineering profession, incorporating programmes to reach female learners, and rural and low-income areas.
- **Bursaries**: Provide bursaries to attract those who excel in mathematics and science to study engineering.

Tertiary education

- **Consolidation:** Consolidate engineering studies into well-resourced universities and institutes to ensure quality output.
- **Accreditation:** The ERB and ZIE to work with ZimCHE and the Department of Quality Assurance and Standards to develop a rigorous accreditation programme to ensure the quality of engineering education using the guidelines of the Washington, Sydney and Dublin Accords.
  - Encourage institutions to develop adequate complex engineering problem-solving content and graduate attributes to satisfy the requirements of the Accords.
- **Industry liaison:** Liaise with industry on a regular basis to ensure that curricula, methods, software and equipment are relevant and up to date and that numbers being trained match the demand.
- **Curricula:** Provide funding to research, modernise or develop curricula and material where required.
- **Facilities:** Raise funding to upgrade lecture theatres, libraries and laboratory facilities where required.
- **Resources:** Raise funding for computers, engineering software, access to online reference material, and laboratory and other equipment, and ensure adequate support to offer technology-relevant training.
- **Additional academics:** Improve conditions of service, support and packages to attract, retain and appoint additional academics.
- **Academic development:** Provide funding for lecturer post-graduate development and facilitate opportunities for academics to gain experience in industry.

Graduate training

- **Develop programmes:** Develop national graduate training programmes to ensure graduates achieve the level of competence required by industry and for professional registration.
- **Private sector incentives:** Offer incentives for private sector companies to develop graduates.
- **Public sector support:** Ensure that public sector structures take on and train graduates and that they are absorbed and developed through the ranks.
- **Institutional support:** Institutionalise graduate training in all organisations by setting KPIs for experienced staff to act as supervisors and mentors.
- **Project support:** Make graduate training a requirement of all public sector projects and ensure that the progress of graduates is monitored, and penalties are imposed for non-compliance.

Registration of engineering professionals

- **Registration:** Update the Act to include a requirement for senior government officials to register and to include recognition of prior learning.

Continuing development

- **CPD:** Support the participation of engineering practitioners in CPD activities.
- **Validation:** Validate short courses and skills programmes for a specified period only to ensure that training remains up to date and relevant.

- **Post-graduate studies:** Provide post-graduate bursaries to develop specialists.
- **Develop managers and leaders:** Encourage industry to continue investing in graduates after professional registration to grow management and leadership capabilities.

Registration of service providers

- **Legislation:** Develop, approve and enforce a National Construction Industry Act to:
  - Cover the increasing use of local consultants, contractors, labour, plant and materials.
  - Ensure that foreign consultants and contractors partner with local companies.
  - Ensure that there are requirements for consultants and contractors to train graduates, artisans and other construction-related skills.
  - Ensure that local consultants and contractors are developed as part of large projects.
  - Ensure that international consultants provide all calculations, drawings, operating manuals and other reference material in English.
  - Ensure that local consultants, along with the client, check that design proposals address local needs and customs and that design calculations comply with national codes and standards.
- **Quality:** Implement quality assurance on all projects and enforce penalties for poor performance.

Public sector

- **Economic infrastructure:** Invest in the development of economic infrastructure such as electricity, roads, rail and airports, and address the supply of water services.
- **Maintenance:** Invest in maintenance to preserve new infrastructure and prevent further deterioration of existing infrastructure.
- **Tariffs and payment:** Review and increase tariffs where appropriate, enhance domestic revenue collection and demand management to fund development.
- **Technical capacity:** Reprioritise budgets to fill vacant posts and build technical capacity, ensure that salaries are competitive and develop succession plans to make the public sector an employer of choice.
  - Materials testers: Equip soil laboratories and fund the development of training for material testers.
- **Technical decision-makers:** Ensure that engineering professionals are employed in senior decision-making posts.

Industry-wide collaboration

- **Advisory team:** Set up an engineering advisory team, recognised by government, to advise on and endorse infrastructure development proposals, tertiary curricula and graduate training programmes.
- **Manpower Development Plan:** The ZIE and ECN to contribute to the development of the National Critical Skills Audit Report and ensure collaboration with tertiary education, and the public and private sectors to determine the demand for, and content of, the qualifications required.
- **Collaboration:** Encourage all professional bodies to work together to share knowledge, exchange best practice and ensure coordinated planning of industry support initiatives.

ACKNOWLEDGEMENTS

The detailed picture presented would not have been possible without the support of many associations, government departments and local professionals. A special thank you to Andrew du Toit for providing many contacts and to Dr Sanzan Diarra, CEO of ZIE, Eng. Dawson Mareya, Vice-Chair, Eng. Ben Rafemoyo, CEO of ECZ and Eng. Martin Manuhwa, VP of WFEO, for making data available and giving advice on the project. Thank you too, to many secretaries who nagged their bosses to provide the data requested and for ideas provided by passionate engineers in various organisations.

SOURCES OF INFORMATION

Data and information were gathered during meetings, interviews and telephone conversations, and via email and Skype. SADC reports, master plans and strategies as listed under *Plans and Strategies*, and many standard international sets of data as listed in Chapter 5, *Research Approach,* were also consulted. Further information was gathered from news articles, such as those published by the *Financial Times, Financial Gazette, Standard, Independent, Herald, Sunday Mail, News Day*, etc. and from Labour Force Surveys. Comprehensive documents focusing on specific issues in Zimbabwe as listed below were invaluable sources of information.

Embassy of India. 2018. *SME Investor Guide for Zimbabwe*. Harare.

Global Water Partnership. 2015. Zimbabwe stakeholder perspectives on a water goal and its implementation. Stockholm.

Maiyaki, A.A. 2010. Zimbabwe's agricultural industry. *African Journal of Business Management*, 4(19): 4159–4166.

Makumbe, J. 2009. *The impact of democracy in Zimbabwe*. University of Zimbabwe, Harare.

Muyambo, A. and Klaassen, W. 2015. *Capacity building for Zimbabwean urban local authorities in water supply needs assessment and business opportunities report*. The Hague: Netherlands Enterprise Agency.

The Ruzivo Trust. 2013. Under the Policy Influencing Project (PIP), the Trust issued 16 PIP Empowerment Fact sheets in 2013, offering detailed analyses and suggested reforms, covering all sectors of the economy.

Viewing, K. 2007. *Professional and technical staff vacancies in the mining industry and implications for replacements*. Report prepared for the Ministry of Mines. [Quoted in 2008 UNDP report (Office of the Resident Representative, Zimbabwe) *Comprehensive Economic Recovery in Zimbabwe.*] Available at: https://www.searchworks.stanford.eu/view/9391021

ZEPARU (Zimbabwe Economic Policy Analysis and Research Unit). 2016. *In-depth training needs assessment survey in the Zimbabwe mining sector*. Harare.

Zimbabwe Parliament Budget Office. 2018. *2018 First Quarter Budget Performance and Outlook Report*. Harare.

ZimStat. 2013. *Census of Industrial Production (CIP), 2013 Report*. Harare.