Chapter 1
Background

Science, technology and innovation (STI) provides the bedrock that is essential to the economic growth of a country and can be considered as the quintessential ingredients for the establishment of a knowledge economy (Lee, Park, & Choi, 2009). As a result, considerable investments in STI are made by governments and industry, with the expectation that these investments will lead to social and economic benefits. Underpinning STI excellence is the availability and access to well maintained research infrastructures (RI) that facilitates the undertaking of leading edge research and the training of highly skilled specialists.

1.1 Why Invest in RIs?

Research infrastructures form a central and integral part of the STI ecosystem as depicted in Fig. 1.1. They provide a platform for the production of new knowledge and innovation. The European Strategy Forum on Research Infrastructures (ESFRI, 2018) notes that RI includes major scientific equipment and infrastructures, cyber-infrastructures (or ICT-based infrastructures), scientific collections, archives and structured information, and entities of a unique nature that are used for research.

According to ESFRI (2018) Research Infrastructure can be defined as the facilities, resources, and related services used by the scientific community for:

- *Conducting leading-edge research;*
- *Knowledge transmission;*
- *Knowledge exchange; and*
- *Knowledge preservation.*

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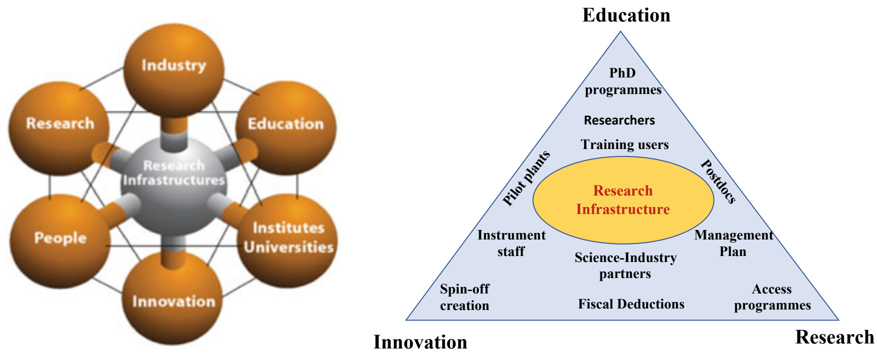

Fig. 1.1 RIs play a central and integral role in the research ecosystem

The motivation and process for investing in RI is informed by national STI strategies aimed at advancing scientific excellence within a country with the objective of finding novel and innovative solutions to socio-economic challenges. Such strategies therefore must align to international trends, policies and goals, such as the Sustainable Development Goals (SDGs) and the Science, Technology and Innovation Strategy for Africa 2024 (STISA, 2024). Intentions for investing in national RI vary based on a country's STI priorities. However, in principle, the goal can be described as follows:

- Supporting and promoting the development of innovative solutions that respond to national and global challenges such as food security, clean water and energy security, health, poverty alleviation, amongst others.
- Enhancing the quality of research undertaken by researchers, students, staff and emerging researchers through improved access to RI and equipment.
- Developing the technical and applications expertise specifically relating to the capacity for operation, maintenance and engineering support of leading edge research. This would contribute towards addressing the skills deficit not only in the country but also on the African continent.
- Inculcating a long-term planning culture relating to the management of research equipment. This inherently links to concepts of asset management, maintenance, support, training and the sustainable management of research equipment over its functional lifespan. Mechanisms must be in place for capital replacement and/or upgrade at the end of the equipment lifespan.
- Promoting regional, national and international approaches that collectively support the RI ecosystem.

1.2 The Innovation Value Chain

Innovation is an outcome of the dynamic interplay between a diverse array of stakeholders within complex systems that are interdependent, non-linear, and increasingly open and collaborative (Global Research Council, 2015). It involves an ecosystem of stakeholders from universities as well as the public and private sectors. Despite their varying investment foci, these stakeholders are able to collectively steer, shape and support the various stages of research, development and innovation. For instance, whilst public sector investments are primarily focused on basic research, as a driver for the development of highly skilled human capital and knowledge outputs, private sector investments are concentrated on the translation of knowledge that can lead to the development of an array of technological innovation, in the form of products, processes and services with direct commercial benefit.

There are essentially four stages in the innovation value chain that involve idea generation (basic research), idea development (applied research), idea testing (technology and prototype development) and the diffusion of developed concepts through commercialisation (Lee et al., 2009; Schot & Steinmueller, 2018). From an RI perspective, a holistic understanding of each phase and how this cumulatively impacts the innovation system is critical. Figure 1.2 gives a schematic example of the innovation value chain aligned to the RI sector. At this stage, it is important to note, that this process is not always linear, as a cyclical and reiterative process often ensues.

Basic Research is commonly defined as a systematic study directed toward gaining knowledge and new ideas or a better understanding of the fundamental aspects of phenomena without specific applications, processes or products in mind (Braun, 1998; United States of America, 2006). Basic research is usually designed to produce codified theories and models that explain and predict reality (Salter & Martin, 2001) and may have direct long term impacts. Basic research, also termed fundamental research or pure research, is an essential element of the innovation ecosystem.

Applied Research is unlike basic research as it is solution-or mission-oriented and aimed at addressing specific challenges that have direct societal benefit. This type of research is aimed at solving societal challenges through the development of innovative products, processes and technologies that impact the life, work, health and general well-being of people (Cherry, 2018).

Technology and Prototype Development Research is defined as a systematic application of knowledge or understanding, directed towards the production of useful materials, devices, and systems or methods. These include the design, development

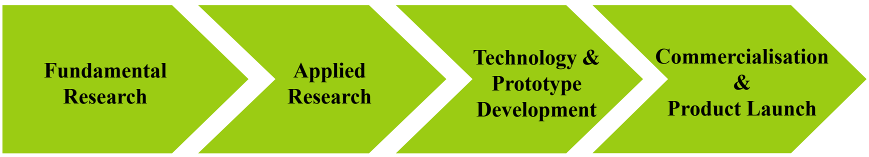

Fig. 1.2 Innovation value chain

and improvement of prototypes and new processes to meet specific requirements (United States of America, 2006).

Commercialisation and Product Launch: After the successful completion of the development phase, there is an upscaling of the full production facility and the innovative product, process or service is launched into the market where its commercial potential is realised.

When looking at the innovation value chain, we can consider the example of the journey towards the development of the smart phone, as presented in Fig. 1.3, which comprises several components, i.e. (i) battery, (ii) GPS, (iii) RAM, (iv) multi-core processors, (v) CPU, and (vi) the touch screen.

Public and private sector partners, heavily invest in either a singular stage or multiple stages of the innovation value chain through universities, research centres, innovation hubs and other public research performing institutions. Despite the evidence that the investment in science may yield economic benefits, both direct and indirect (Fedderke, 2001; National Advisory Council on Innovation, 2004; Organisation for Economic Co-operation and Development, 2008; Salter & Martin, 2001), the return on the co-investments by both public and private sector partners has led to numerous contradictory arguments being presented. On the one hand, academics are renowned for (i) generating knowledge outputs in the form of publications, (ii) training students at various levels, and (iii) obtaining additional research capital. Industry partners, on the other hand, position themselves for increased market competitiveness through patents acquired, new or improved products, services and/or improved processes for new and/or enhanced product quality (Organisation for Economic Co-operation and Development, 2008). Compounding this challenge is the innovation chasm, which is underpinned on the theory of constraints. The consequential result associated with this challenge is the the low probability rates of translating academic research into marketable products, processes and/or services (Salter & Martin, 2001).

> "*Innovation in whatever form follows a power law: for every truly radical idea that delivers a big dollop of competitive advantage, there will be dozens of other ideas that prove to be less valuable. But that's no excuse not to innovate. Innovation is always a numbers game; the more of it you do, the better your chances of reaping a fat payoff.*" Hamel (2006)

In order to derive maximum returns from the STI investments from public sector, a holistic and well balanced approach that takes into account the entire innovation value chain must be considered. For instance, the Global Research Council (2015) identifies the following exemplars for strengthening the interplay between basic research and innovation.

- **Research underpins innovation and societal benefits**: A vibrant research ecosystem is essential to developing the talented individuals who will pursue curiosity-driven research as they respond to the world's pressing challenges and become leaders in the global knowledge and skills economy.

Component	Basic Research	Applied Research	Technology and Prototype Development	Commercialisation and Product Launch
Battery 	Started off with elementary chemistry research that was focused on the characterization of materials. Research on lithium batteries was led by British chemist M. Stanley Whittingham, in the 1970s, while working for Exxon (Whittingham, 1976).	Further discoveries on the use of less expensive, alternative materials for the batteries were made by Whittingham whilst he was at the University of Texas. The research was funded by the National Science Foundation and the Department of Energy (Whittingham, 1976).	Rechargeable lithium-ion batteries were made possible by the invention of lithium cobalt oxide cathode materials by physicist John Goodenough during his time at Oxford University (Mizhushima, Jones, Wiseman and Goodenough, 1980).	**Smartphones available in the market place.** 
GPS 	Research on satellite navigation systems has its foundations in Einstein's theory of relativity, and is based largely on the invention of molecular-beam magnetic resonance by Rabi, Millman, Kusch and Zacharia (1939).	Work on the cesium-beam atomic clock began and in 1955, the first accurate atomic clock was built at the National Physical Laboratory in the UK (Essen and Parry, 1955).	The Soviet Union launches Sputnik into space in 1957. The USA Department of Defence and NASA, the team developed the Transit Navigation Satellite System (Danchik and Pryor, 1990).	
RAM 	Basic research was conducted in the areas of electromagnetic physics (Ulaby and Ravaiolo, 2015).	MIT researcher Jay Wright Forrester performed the U.S. Navy-supported research that resulted in the creation of the first magnetic core RAM in the 1940's by Jay W. Forrester (Lane and Sterman, 2018).	Dynamic Random Access Memory was developed by Robert H. Dennard and this technology used in World War 2. The technology is now used in digital electronics where low-cost and high-capacity memory is required such as computers and graphic cards (Dennard, 2018).	
Multi-core processors 	Basic research can be traced back to semiconductor-physics and chemistry. The origins thereof is founded on Moore's law and Michael Faraday's explorations in the 1800's on negative temperature coefficient of resistance of silver sulphide (Ulaby and Ravaiolo, 2015).	The First Draft of a Report on the EDVAC by John von Neumann described the first logical design of a computer using the storage programme concept (1945). Professor Kunle Olukotun and his research group at Stanford University in 1995 used USA Department of Defence funding to develop the first multicore processor, which allowed computers to become more responsive and powerful with less heat generation (von Neumann, 1945).	Modern day transistors are based on the principles of semiconductors and are the building blocks of electronic circuits. Before processors with multiple cores were built, researchers and companies such as Intel tried to build computers with multiple CPUs. After much experimentation, CPUs with multiple cores form part of modern day computers (de Looper, 2015).	
Touch screen 	Touch screen technologies can be traced back to electromagnetic physics and Faraday's law of induction (Ulaby and Ravaiolo, 2015).	The resistive touch screen (a screen that can be manipulated with a finger or stylus) was developed in 1971 by Samuel Hurstat the University of Kentucky, who was founder of Elographics (Bellis, 2018).	In 1974, the first true touch screen incorporating a transparent surface came on the scene developed by Sam Hurst and Elographics. In 1977, Elographics developed and patented a resistive touch screen technology, the most popular touch screen technology in use today (Bellis, 2018).	

Fig. 1.3 Example of smart phone technology that has passed the various stages of the innovation value chain

- **Collaboration and dialogue is critical within the innovation ecosystem**: Linkages between publicly funded research organisations and industry may result in information and knowledge exchange that can inform the direction of research, allocation of investments, and the quality of innovation outcomes.
- **Evaluate impact**: Great attention should be given to the respective time frames of research, industry and other societal spheres. The methods used to judge success determine how research is monitored, evaluated, valued and funded, and how risk is perceived and acknowledged as part of the process.
- **Strengthen intra-regional cooperation**: Connectivity and collaboration at a regional level should recognise regional challenges and values whilst enhancing the opportunities for increasing the relevance of research and the outputs from the research and innovation process.
- **Nurture talent and enhance skills development**: Researchers and trainees who are internationally mobile, who work at the interface between disciplines, or who acquire work experience outside of academia, enlarge and strengthen the innovation system by facilitating knowledge transfer, diversity of viewpoints, cultural adaptation, and entrepreneurship.

1.3 An Overview of the STI Policy and Strategy Landscape in South Africa

This section builds on the provisions of the Research Development and Innovation Funding Framework that was developed by the Department of Science and Technology (DST) in 2010 (South African Department of Science and Technology, 2010). It maps the key policy milestones within the South African historical STI journey, which starts at the time of democracy in 1994, when a National Research and Development audit was undertaken. The key findings were that South Africa was still lagging behind other developing nations competing and collaborating in international research programmes, and that new financing for large research and development (R&D) equipment was a critical success factor for South African scientists to be globally competitive (South African Department of Arts, Culture, Science and Technology, 1996). Several policy frameworks and concept documents were subsequently developed with the objective of proposing interventions for improving the capacity to undertake competitive research and training by investing in human capital development and the procurement and upgrade of RI.

In 1996, South Africa's White Paper on Science and Technology was developed which focused on three pillars of investment: (i) innovation; (ii) science, engineering and technology, with a strong focus on human capital development and transformation; and (iii) creating an effective national science and technology system. The paper highlighted the need for highly specialised infrastructural platforms such as national research facilities to undertake cutting edge scientific research. The White Paper further made provision for the purchase and maintenance of expensive research equipment on the basis that:

- The placement of research equipment facilitates access to the wider research community with a specific focus on closing the gaps in the differentiated higher education landscape in the country.
- The research equipment is placed at a research institution with high achieving researchers in a specific discipline which will be advanced as a consequence of the placement of the equipment.
- The research institution co-invests in the procurement of the research equipment (South African Department of Science and Technology, 2010).

In 2002, the National R&D Strategy for South Africa was published, articulating the following pertinent recommendations:

- Scientific instrumentation is important for advancing research, economic growth and human capital development.
- Modern, well-maintained equipment is a pre-requisite for high quality research.
- Equipment has considerable economic impact, particularly in the manufacturing sector.
- The use of equipment in the educational sector is a key success factor in nurturing curiosity-driven research, and developing the requisite skills for undertaking world class research and supporting the advancement of modern industry (National Research Foundation, 2004; South African Department of Science and Technology, 2002).

In 2010, the Research, Development and Innovation Infrastructure Funding Framework was developed that identified five investment areas: (i) scientific equipment; (ii) high-end infrastructure; (iii) specialised facilities; (iv) access to global infrastructures; and (v) cyber-infrastructure (South African Department of Science and Technology, 2010). Critical to these areas of investment is the (i) management and access to large data sets that are produced or collected from research equipment; (ii) the exploitation and/or re-use of that data for enabling other fields and/or areas of research to be explored; and (iii) skilled operators, technicians and engineers to maintain and optimally utilise cutting edge research equipment (South African Department of Science and Technology, 2010).

In 2012, the National Development Plan (NDP) was launched with the objective of eliminating poverty and reducing inequality in South Africa by the year 2030. This would be achieved by (i) drawing on the energies of the people; (ii) growing the economy; (iii) building capabilities; (iv) enhancing the capacity of the country; and (v) promoting leadership and partnerships (South African National Planning Commission, 2012). The NDP embraces the concept of the triple helix whereby government, universities and the private sector aid in the translation of basic research into commercially viable products, processes and services. It further identifies STI as a primary driver of economic growth, job creation and socio-economic reform (South African Department of Science and Technology, 2019). Integrally linked to this driver, is the provision of research infrastructures that form a critical enabler for developing an equitable STI landscape in the country.

"R&D has played an important role in helping middle-income countries such as South Korea advance to high-income status. While South Africa needs to spend more on R&D in general, the institutional set-up also needs to improve the link between innovation and the productive needs of business. Government should partner with the private sector to raise the level of R&D in firms. Public resources should be targeted to build the research infrastructure required by a modern economy in line with the country's development strategy." (South African National Planning Commission, 2012).

In 2016, the South African Research Infrastructure Roadmap (SARIR) was launched with the objective of providing a framework for the provision of the research infrastructures necessary for a sustainable national system of innovation (Pandor, 2016). This roadmap articulates the commitment of the South African government to research infrastructure development in the country. The investment in SARIR expresses a deep understanding of the importance of excellent research infrastructure as a critical enabler for undertaking excellent research. The roadmap identifies 13 potential investments of interest in RI in South Africa that are classified according to thematic areas. The investment in the 13 RIs must be viewed holistically and not in isolation from each other as there are a number of shared experiences, learnings, outputs and solutions that can be gained (South African Department of Science and Technology, 2016) (Table 1.1).

In 2019, a White Paper on Science and Technology was developed, that lays out the long term policy approach of the STI sector and emphasises the core themes of (i) inclusivity; (ii) transformation; and (iii) partnerships. The White Paper continues to expand the investment in research infrastructures, cyber-infrastructure and access to global research facilities. It also reviews the achievements and milestones since 2002, in a manner that creates a learning platform for sharing experiences, lessons, outputs and solutions (South African Department of Science and Technology, 2016). Whilst the White Paper builds on the successes and lessons since 1996, it also proposes and adopts new approaches to nurture creativity, learning and entrepreneurship. The key objective is to actively contribute toward the targets set forth in the NDP (South African Department of Science and Technology, 2018).

A summary of the above-mentioned policies and strategies, informing the investment in RIs over the past 25 years is presented in Fig. 1.4.

Table 1.1 Summary of the RIs identified for funding in the SARIR (South African Department of Science and Technology, 2016)

RI Domain	Identified RI
Human and social dynamics	The South African Network of health and demographic surveillance sites
	National Centre for Digital Language Resources (NCDLR)
Health, biological and food security	Distributed Platform for "Omics" Research (DIPLOMICS)
	Biobanks
	Nuclear medicine
Earth and environmental	A South African marine and antarctic research facility
	Biogeochemistry research infrastructure platform
	An expanded national terrestrial environmental observation network
	Shallow marine and coastal research infrastructure
	The natural sciences collection facility
Materials and manufacturing	Materials characterisation facility
	Nano-manufacturing facility
Energy	Solar research facility

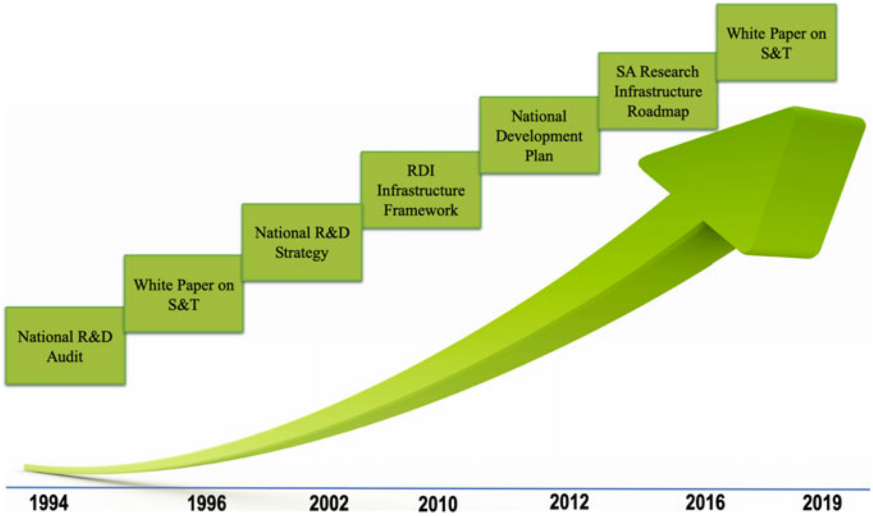

Fig. 1.4 An illustrative timeline representation of the key policies and strategies framing RI investments in South Africa

1.4 Role of the Funding Agency in the STI Policy Landscape in South Africa

Public research funding agencies are quasi-public organisations mandated by specific national legislative acts or laws. Although they are independent entities, they are still dependent on government for financial resources. Through the resources they manage, funding agencies play a central role in driving research and human capacity development programmes that meet specific requirements and criteria through the use of grant awarding processes to encourage research productivity from recipients of grants (Braun, 1998). Funding agencies can, therefore, be considered protagonists in the distribution of public resources and structure the way research is conducted by the stipulation of criteria and conditions linked to research grants (Braun, 1998). Research funding agencies also play a key leadership role in stimulating interest in young people to pursue careers in science and technology and developing a diverse labour force with the necessary skills to navigate in a knowledge economy (Lee et al., 2009).

The National Research Foundation (NRF) is the public funding agency in South Africa that was established as an independent government agency in 1998 (South Africa, 1998). The role of the NRF in the national context is summarised in Fig. 1.5. The mandate of the NRF is to contribute to national development by: supporting, promoting and advancing research and human capital development, through funding

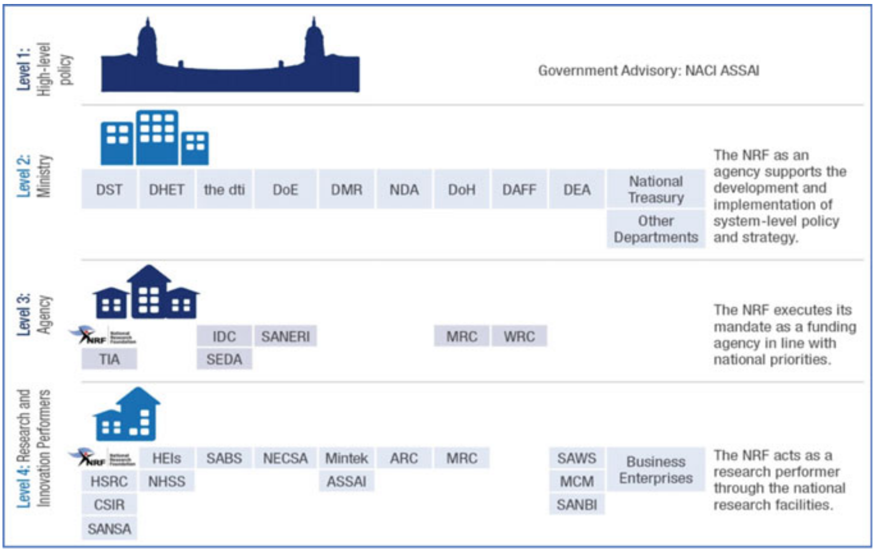

Fig. 1.5 The NRF within the South African research ecosystem (National Research Foundation, 2015)

and the provision of the necessary research infrastructure, in order to facilitate the creation of knowledge, innovation and development in all fields of science and technology, including humanities, social sciences, and indigenous knowledge; developing, supporting and maintaining national research facilities; supporting and promoting public awareness of, and engagement with, science; and promoting the development and maintenance of the national science system and support of Government priorities (South Africa, 2018). As such, the NRF, is responsible for the awarding of public funds utilising competitive review processes to public research performing institutions, including, but not limited to (i) universities; (ii) science councils; (iii) research laboratories; (iv) research hospitals; (v) research museums; and (vi) national research facilities, amongst others. Much of the content of this document draws on the processes and policies of the NRF.

1.5 Navigating a Differentiated Higher Education Landscape

To speak of a single, homogenous higher education system 25 years post-democracy would be painting an idealistic perspective with no consideration afforded to the social injustices and legacy left behind by the Apartheid regime (Mekoa, 2018; Reddy, 2004). The different types of universities under the new democratic government are still plagued by issues such as (i) unequal funding; (ii) skewed demographic profile of students and staff; (iii) inadequately skilled or trained academic staff to lead research projects and/or supervise postgraduate students; (iv) institutional histories; (v) varying levels of support from industry as well as regional and local communities surrounding universities; and (vi) varying impacts of the evolving social discourses and national policy priorities (Mekoa, 2018; Reddy, 2004). In addition, there is a high level of variation with regards to ownership and access of RI within the higher education sector. These factors highlight the marked differences in status, infrastructure and capacities between those universities that are considered “historically advantaged” or “resource-rich” that previously catered for the minority white population; and those that are considered “historically disadvantaged” or “under-resourced” universities that were created by the Apartheid government to produce and domesticate emerging black elites. The latter, however played a pivotal role in eroding the legitimacy of the unjust Apartheid social form (Mekoa, 2018; Reddy, 2004).

> *Due to the legacy of the Apartheid system, the higher education landscape in South Africa remains highly differentiated despite efforts to reform the higher education system* (Mekoa, 2018; Reddy, 2004).

At the time of the democratic transition, the higher education landscape was comprised of 21 public universities and 15 technikons (Reddy, 2004). Post-1994,

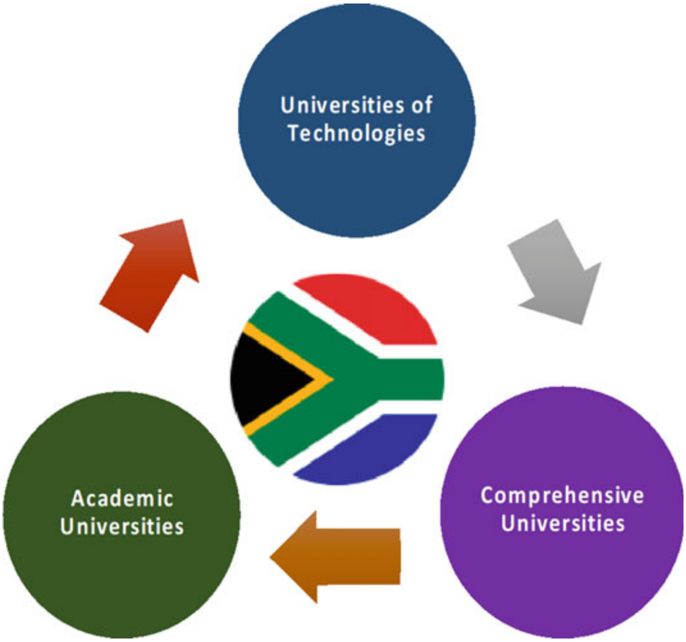

Fig. 1.6 Types of universities that comprise the South African higher education system

these higher education institutions were subjected to legal, administrative and policy changes which resulted in the morphing of the national higher education landscape. As of 2018, the university education system in South Africa comprises 26 public universities that can be classified as (i) 11 academic universities; (ii) nine comprehensive universities; and (iii) six universities of technology (South African Department of Higher Education and Training, 2016) (Fig. 1.6).

Universities of Technology: These universities have transformed from their original technikon status and offer more vocational-orientated or technical programmes or qualifications. The six institutions listed in alphabetical order below include:

- Central University of Technology
- Cape Peninsula University of Technology
- Durban University of Technology
- Mangosuthu University of Technology
- Vaal University of Technology
- Tshwane University of Technology.

Comprehensive Universities: These universities are a result of a merger between academic universities and technikons with the objective of enhancing institutional diversity at higher education institutions through the strengthening of synergies between career-focused and general academic programmes (South African Department of Education, 2004). These nine institutions are listed in alphabetical order below:

- Nelson Mandela University
- Sefako Makgatho University
- Sol Plaatjies University
- Walter Sisulu University
- University of Johannesburg
- University of Mpumalanga
- University of South Africa
- University of Venda
- University of Zululand.

Academic Universities: These universities offer more traditional theoretically-orientated academic-based training. The following eleven institutions are listed in alphabetical order below:

- North West University
- Rhodes University
- University of Cape Town
- University of the Free State
- University of Fort Hare
- University of KwaZulu Natal
- University of Limpopo
- University of Pretoria
- University of Stellenbosch
- University of Western Cape
- University of the Witwatersrand.

The 26 universities are spread across the country with the majority (eight) based in Gauteng, which is the smallest and most populous province in South Africa with approximately 14.7 million people (Statistics South Africa, 2018). The Western Cape and KwaZulu Natal come in second place by hosting four universities each. The Eastern Cape has three universities followed by Limpopo and the Free State which host two universities each. The least number of universities are in Northern Cape, Mpumalanga and the North West, each hosting one university. Figure 1.7 provides are illustrative map indicating the location of public universities in South Africa.

This classification system of the higher education landscape in South Africa is further entrenched by the performance indicators for this sector by government, which is largely based on research and/or research-related indicators. Public debate ensues with the objective of expanding the set of indicators. Muller (2013) suggests that the following indicators be utilised to assess performance at the higher education institution level:

- Undergraduate and postgraduate enrolment numbers.
- Number of academic staff by rank.
- Number of permanent academic staff with Ph.D.s.
- Number of research publications.
- Number of Ph.D. enrolments and graduates.

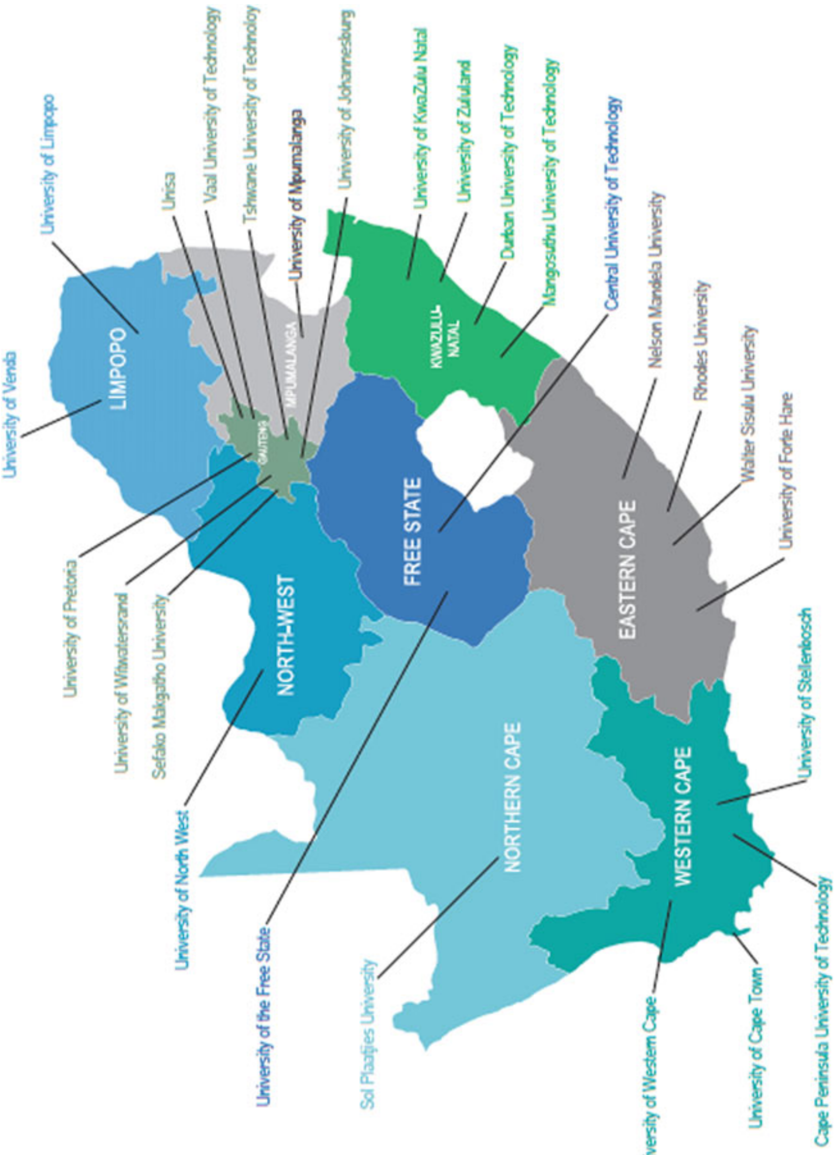

Fig. 1.7 The geographical spread of universities across the nine provinces in South Africa

To develop a holistic set of indicators will require a wider consultative process to be employed that focuses on identifying and understanding the needs and influencing factors impacting on the rather differentiated higher education sector in the country. Such factors include, amongst others, the strength of the institution's balance sheet and how this, in turn, contributes to the research institution's ability to deliver on the key performance indicators aligned to both knowledge generation and human capital development.

1.6 Overview of Research Infrastructure Investments in South Africa

Given the diverse and vital role that infrastructure plays in the research ecosystem as well as the associated high cost implications, the investment in infrastructure should be holistically planned and executed taking into account strategic leveraging and sharing of resources among key stakeholders at the national, regional and global levels.

In 2006, a study by Piperakis and Pouris highlighted the huge deficit of modern research equipment in South Africa. However, during the past decade, significant investments have been made through the NRF and its line department with the aim of improving the state of research equipment at research performing institutions in South Africa. As of February 2019, the NRF had awarded a total of 408 grants to 33 research institutions, comprising 23 universities and ten other research performing institutions, which includes non-degree awarding research performing institutions such as national research facilities and other public science councils, laboratories and museums, amongst others (National Research Foundation, 2018). The investment by the NRF is summarised in the Fig. 1.8.

Figure 1.9, indicates that the biggest recipient of NRF research equipment grants are those institutions based in Gauteng, which is not only home to the largest number of universities but is also considered to be the economic hub of the country, if not the continent.

It is not surprising, that academic universities have benefited significantly from the NRF equipment grants as seen in Fig. 1.10. This is largely attributable to their research intensive activities, which have held them in good stead when subjected to the scorecard linked to the NRF's equipment grants, which is discussed in detail in Chap. 3 (National Research Foundation, 2018).

1.7 Summary

This chapter provides a contextual background of the underlying policies and strategies that motivate the provision of RI which is deemed a critical enabler for the

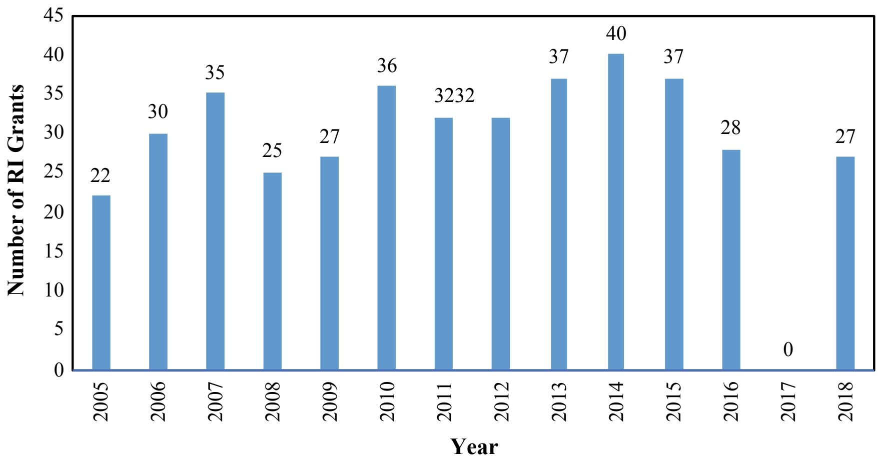

Fig. 1.8 Number of equipment grant awards per annum spanning the period from 2005 to 2018 (National Research Foundation, 2018)

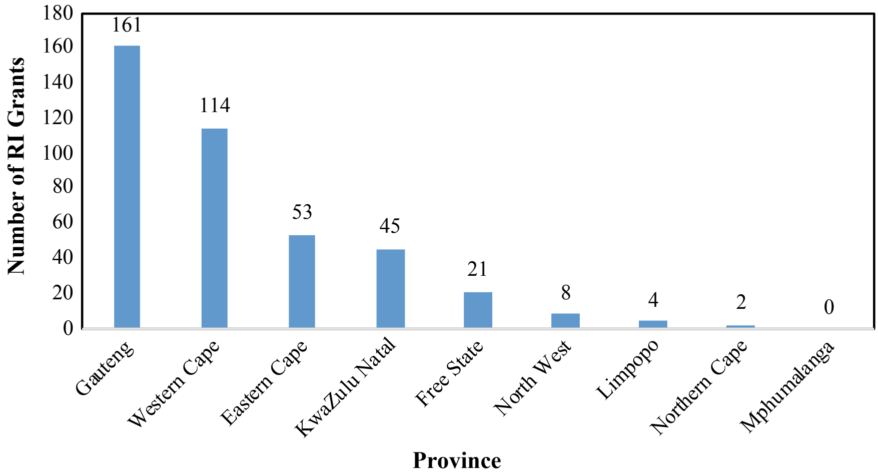

Fig. 1.9 Provincial distribution of equipment grants across the higher education landscape in South Africa (National Research Foundation, 2018)

realisation of the key national objectives and priorities. It also highlights some of the challenges that continue to face the higher education landscape in the country, and summarises the spread of investments made by the NRF in implementing the RI funding instruments over a 15 year time frame across this rather differentiated higher education sector.

This chapter sets the scene for further discussion on the approaches employed in the South African context to classify categories of infrastructure funding.

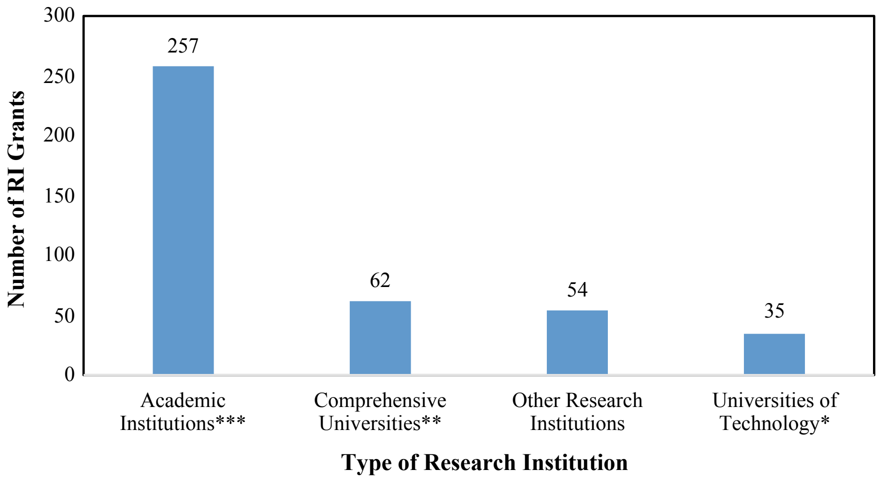

Fig. 1.10 Spread of equipment grants across the various types of research institutions in South Africa (National Research Foundation, 2018). *Only five of the six universities of technology received equipment grants. **Only seven of the nine comprehensive universities received equipment grants. ***All academic universities received grants

References

Braun, D. (1998). The role of funding agencies in the cognitive development of science. *Research Policy, 27,* 807–821.

Cherry, K. (2018). *How applied research is used in psychology*. [online] Available at https://www.verywellmind.com/what-is-applied-research-2794820. Accessed on January 4, 2019.

European Strategy Forum on Research Infrastructures. (2018). *Strategy report on research infrastructures.* [online] Available at http://roadmap2018.esfri.eu/media/1060/esfri-roadmap-2018.pdf. Accessed March 1, 2019.

Fedderke, J. W. (2001). *Growth and innovation report.* [online] Available at http://www.naci.org.za/pdfs/growth_innov_2001.pdf. Accessed on May 25, 2009.

Global Research Council. (2015). *Statement of principles for funding scientific breakthroughs.* [online] Available at https://www.globalresearchcouncil.org/fileadmin/documents/PDF_Links/Statement_of_Principles_for_Funding_Scientific_Breakthrough.pdf. Accessed on January 12, 2019.

Hamel, G. (2006). The why, what, and how of management innovation. *Harvard Business Review, 84*(2), 2–12.

Lee, H., Park, Y., & Choi, H. (2009). Comparative evaluation of performance of national research and development programmes with heterogeneous objectives: A DEA approach. *European Journal of Operational Research, 196,* 847–855.

Mekoa, I. (2018). Challenges facing Higher Education in South Africa: A change from apartheid education to democratic education. *African Renaissance, 15*(2), 227–246.

Muller, J. (2013). *On different pages in the differentiation debate*. [online] Available at http://www.universityworldnews.com/article.php?story=20130215131939198. Accessed November 8, 2017.

National Advisory Council on Innovation. (2004). *South African innovation key facts and figures*. [online] Available at http://www.naci.org.za/Innovation_gateway/downloads/Innov_FF.pdf. Accessed 2 June 2, 2017.

National Research Foundation. (2004). *National key research and technology infrastructure strategy*. [online] Available at http://eqdb.nrf.ac.za/sites/default/files/resources/national%20key%20research%20and%20technology%20strategy.pdf. Accessed September 2, 2017.

National Research Foundation. (2015). Annual performance plan 2015/16–2017/18 Available at https://www.nrf.ac.za/sites/default/files/documents/NRF%20APP%202015_FINAL_20%20April%202015.pdf.. Accessed May 3, 2019.

National Research Foundation. (2018). *Research equipment database*. [online] Available at http://eqdb.nrf.ac.za/funding. Accessed October 10, 2018.

Organisation for Economic Co-operation and Development. (2008). *Science and innovation: Country notes, South Africa*. [online] Available at http://www.oecd.org/science/inno/41551978.pdf. Accessed January 12, 2018.

Pandor, N. (2016). Official address: Launch of the South African research infrastructure roadmap. In International Conference on Research Infrastructure (ICRI, 2016), Cape Town International Convention Centre, South Africa, October 6, 2016.

Piperakis, M., & Pouris, A. (2006). The state of research equipment in South Africa: Towards best practice. *South African Journal of Industrial Engineering, 17*(1), 75–90.

Reddy, T. (2004). *Higher education and social transformation: A South Africa case study*. [online] Available at http://www.che.ac.za/sites/default/files/publications/HEandSocialTransformationReport_25Feb2004.pdf. Accessed November 16, 2017.

Salter, J. A., & Martin, B. R. (2001). The economic benefits of publicly funded basic research: A critical review. *Research Policy, 30,* 509–532.

Schot, J., & Steinmueller, E. (2018). *Three frames for innovation policy: R&D, systems of innovation and transformative change*. Available at https://www.sciencedirect.com/science/article/pii/S0048733318301987?via%3DihubAccessed November 10, 2019.

South Africa. (1998). *National research foundation act 23 of 1998*. [online] Available at http://www.nrf.ac.za/sites/default/files/documents/NTFAct.pdf. Accessed October 2, 2018.

South Africa. (2018). *National research foundation amendment bill*. [online] Available at http://pmg-assets.s3-website-eu-west-1.amazonaws.com/180529B23b-2017.pdf. Accessed May 2, 2019.

South African Department of Arts, Culture, Science and Technology. (1996). *White paper on science and technology: Preparing for the 21st century.* [online] Available at http://www.esastap.org.za/download/st_whitepaper_sep1996.pdf. Accessed October 2, 2017.

South African Department of Education. (2004). *Creating comprehensive Universities in South Africa: A concept document*. Available at http://www.dhet.gov.za/Management%20Support/Creating%20Comprehensive%20Universities%20in%20South%20Africa%20A%20concept%20document.pdf. Accessed October 26, 2018.

South African Department of Higher Education and Training. (2016). *Statistics on post-school education and training in South Africa*. [online] Available at http://www.dhet.gov.za/Research%20Coordination%20Monitoring%20and%20Evaluation/6_DHET%20Stats%20Report_04%20April%202018.pdf. Accessed April 1, 2018.

South African Department of Science and Technology. (2002). *National research and development strategy*. [online] Available at http://www.esastap.org.za/download/sa_natrdstrat_aug2002.pdf. Accessed January 12, 2017.

South African Department of Science and Technology. (2010). *Research, development and innovation funding framework.* [online] Available at https://notices.ukzn.ac.za/content/GetFile.aspx?id=1424. Accessed January 12, 2016.

South African Department of Science and Technology. (2016). *South African research infrastructure roadmap*. [online] Available at https://www.dst.gov.za/images/Attachments/Department_of_Science_and_Technology_SARIR_2016.pdf. Accessed May 12, 2018.

South African Department of Science and Technology. (2019). *White paper on science, technology and innovation*. [online] Available at https://www.gov.za/sites/default/files/gcis_document/201809/41909gon954.pdf. Accessed October 12, 2018.

South African National Planning Commission. (2012). *National development plan*. [online] Available at https://www.gov.za/sites/default/files/NDP-2030-Our-future-make-it-work_r.pdf. Accessed October 12, 2017.

Statistics South Africa. (2018). *Mid-year population estimates*. [online] Available at http://www.statssa.gov.za/publications/P0302/P03022018.pdf. Accessed October 10, 2018.

United States of America. (2006). *Federal definitions of basic research, applied research, and development.* [online] Available at http://www.er.doe.gov/bes/definitions.html. Accessed June 13, 2017.