POLICY OPTIONS FRAMEWORK FOR THE FOURTH INDUSTRIAL REVOLUTION IN SOUTH AFRICA

An output of the

SA-EU Strategic Partnership Dialogue Conference

Disruptive technologies and public policy in the age of the Fourth Industrial Revolution

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"The Fourth Industrial Revolution (4IR)
is a global phenomenon"

Foreword

The Fourth Industrial Revolution (4IR) is a global phenomenon, which requires an international response. The European Union (EU), as one of the world's major economic blocs, and South Africa, as Africa's most industrialised economy and a gateway to the continent, therefore require coordination and collaboration in the arena of the 4IR. The SA-EU Strategic Partnership Dialogue Facility, together with the Department of Science and Technology and the Human Sciences Research Council, hosted a Dialogue Conference on *Disruptive technologies and public policy in the age of the Fourth Industrial Revolution*, bringing together European and South African experts and stakeholders. The Dialogue facilitated the exchange of ideas about key 4IR topics, leading to the development of a high-level policy framework, and the identification of pathways for further engagement between the EU and South Africa regarding joint cooperation in identified science, technology and innovation areas, with the ultimate aim of leveraging the 4IR for the public good.

The Policy Framework maps and explores the scope of possible policy responses to the 4IR. The Framework summarises and organises the key ideas and discussions emerging from the Dialogue conference, and therefore represents a synthesis of the collective insights of the 36 conference speakers, the 12 members of the steering committee, the supporting teams from the DST, HSRC, and EU Delegation to South Africa, and the over 100 conference delegates over three days of intensive discussion and debate[1].

[1] Further details of the conference, including proceedings, can be found in the accompanying Dialogue Conference report.

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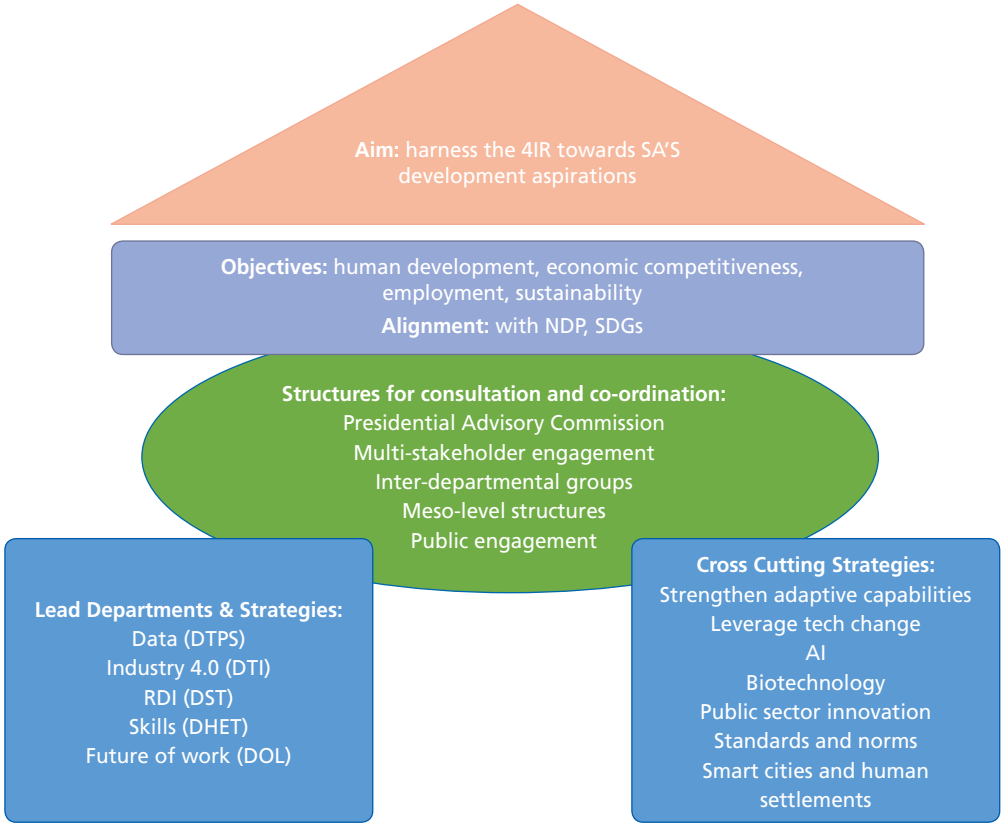
Executive Summary

The purpose of a national Fourth Industrial Revolution (4IR) policy framework is to harness the power of the 4IR towards the achievement of South Africa's developmental aspirations. The Framework presented here consists of a proposed set of aims, objectives, structures, and strategies. A 4IR policy framework needs to provide guidance for policy makers in all spheres to build evidence-informed, responsive and future-oriented policy. Due to the broad and cross-cutting nature of the 4IR, no framework can be exhaustive in its assessment of the potential applications of technologies, or its assessment of the human development roles these technologies might play. We therefore need to support the development of functions within policy-making structures to make such determinations independently. Adaptiveness is indeed an imperative which intersects with the full technological and developmental scope of the Framework, and should be a consideration in the development of all policy mechanisms and interventions.

Figure 1: abstract of a national 4IR policy options framework



Executive Summary

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The aims, objectives, strategies, and structures of the framework are informed by three main areas of consideration:

1. *Alignment with values and policy* informs aims and objectives
2. *Strategic focus areas* inform cross-cutting strategies, as well as strategies led by specific government departments:
    a. Strengthen adaptive capabilities
    b. Leverage technological change
    c. Build 4IR capabilities
    d. Towards developmental outcomes
3. *Structures for consultation and co-ordination*

1. Align with values and policy

To steer the 4IR correctly, policy must be aligned with our developmental goals, for example as articulated in the National Development Plan (NDP), and as expressed in the Sustainable Development Goals (SDGs). There must also be alignment between departmental policies. Both the process and the outcomes of the strategy need to be transformative and inclusive.

The 4IR raises a number of ethical questions, including questions related to data privacy, responsibility for autonomous drones and vehicles, the bioethics of genetic modification, and the societal and developmental impacts of social media and internet use on individuals and populations. Each of these issues requires ongoing engagement among stakeholders, and a research response, in order to inform the policy development process in an ethical manner.

A national policy framework should be preceded by, and include, ongoing dialogue over the language of the 4IR, and how it might best be framed in the South African public sphere. It may be the case that, like other countries, South Africa coins its own term to describe its contextualised approach to accelerating technological change and technological disruption.

2. *Strategic focus areas* inform cross-cutting strategies, as well as strategies led by specific government departments:

2.a. Strengthen adaptive capabilities

Rapid and accelerating technological change is a central proposition of the 4IR concept. We therefore aim towards responsiveness and adaptability, both as a policy objective in a variety of domains (e.g. labour markets, innovation systems) and as a characteristic of policy mechanisms that need to function effectively in a context of rapidly changing technologies and socio-economic dynamics. The South African response to the 4IR will require an increased capacity to be responsive to technological change - to sense changes in the global and local technological environments, and to interpret these changes in terms of their relevance to economies, society, institutions, and policy.

2.b. Leverage technological change

The Framework explores means to leverage specific technologies that are currently causing widespread disruption, for example AI, IIOT, genetic modification, robotics, and 3D printing. Each technology, and each converged application of technologies, presents a distinct set of policy imperatives and opportunities, and hence forms a distinct component of the overall Framework. At the same time, the technological scope that informed the World Economic Forum's 2016 concept of the 4IR has already shifted. The technological scope of the national policy response will need to change over time, as existing technologies plateau, and new ones emerge to cause as yet unimagined disruptions.

Data policy:

- The Department of Telecommunications and Postal Services is leading the development of data policy.
- Data policy needs to be aligned with other components of the Framework, including policy for Industry 4.0, artificial intelligence, biotechnology, and capability-building.

Executive Summary

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- Globally there is a policy tension between the imperative of open data and the imperative of data privacy. Achieving a balance between these two opposing principles is an important part of an overall approach to data policy.
- We need to look at measures to reduce the cost of data for the poor. The question of spectrum allocation is salient here. If one places the digital divide at the centre of the analysis, the question of data costs for poor people in South African might be the most critical issue in the overall South African response to the 4IR.
- A national data policy would need to steer the rollout of 5G networks. Splicing is an option that merits exploration, taking into account questions of data access and questions of enabling Industry 4.0 in South Africa.
- South Africa must support data sovereignty and internalise the beneficiation of South African data.
- Cyber security is increasing important to national security. South Africa's cyber security systems may require enhanced artificial intelligence capabilities.
- Ongoing review of the impact of the 4IR in the financial sector is needed in order to safeguard financial stability.
- South Africa's Information Regulator protects data privacy and helps South Africa meet international privacy standards. This function may in future play a greater role and require expanded capabilities.

Artificial intelligence:

Many countries have developed or are developing national AI strategies. A South African AI strategy should be aligned with and integrated with a national 4IR strategy. AI strategy includes many components and logics similar to a 4IR strategy, including the need to build skills and broad-spectrum research, development and innovation (RDI), stimulate investment, set legal and regulatory frameworks, address ethical issues, build public awareness, and seek application that meets developmental aims. At an operational level, the technological fundamentals of machine learning applications do not have to be developed de novo – off-the-shelf machine learning systems are freely or commercially available. South Africa therefore needs to strike a balance between building scientific capabilities in the AI domain, and building technological capabilities in the domain of AI applications.

Industry 4.0

The concept of Industry 4.0 overlaps with, but is distinct from, the notion of the 4IR. The notion of the 4IR has a broader global socio-political component, while Industry 4.0 has a production focus, specifically on production automation through the use of cyber-physical systems and advanced manufacturing technologies such as autonomous and collaborative robots, simulations, systems integration, the industrial internet of things (IIOT), additive manufacturing (3D printing), and human-machine interfaces. In South Africa, Industry 4.0 policy is spearheaded by the Department of Trade and Industry, where a dedicated 4IR directorate has been established, and policy formulation is in progress at the time of writing. Industry 4.0 policy would ideally be integrated with data policy, due to its reliance on a permanently connected network of devices and equipment. A policy framework for industry 4.0 would benefit from a sector-specific focus, since the manifestation of industry 4.0 has distinct characteristics in each sector.

Biotechnology

Biotechnology is critical technology within the 4IR, not only in terms of the changes it drives in sectors such as agriculture and health care, but in the changes it is precipitating to the human body and identity. South Africa's national bioeconomy strategy, and its genetic modification regulatory framework, form important parts of an overall 4IR policy system. A national 4IR framework may need to review this policy and regulatory space, seeking to

leverage biotechnology for the public good, while also seeking alignment with data policy, industry 4.0 policy, and AI policy, amongst other areas. Some specific areas for consideration include regulatory costs and data bias. High regulatory costs can prevent new GM technologies, developed within SA universities, from benefitting the public. In the medical sphere, South Africa has a responsibility to counter the consistent global bias in global genetic databases, which largely exclude African populations (even though African populations are the most genetically diverse in the world).

2.c. Build 4IR capabilities

Building capabilities is a prerequisite for growing economic competitiveness or effectively applying technologies to meet human development aims. Key areas of capability include our systems of innovation, our education system, the organs of state, and metro-level systems.

Education

- Strengthen the capacity of post-school education institutions to engage with employers and understand their current and potential future skills requirements
- Aim to shorten the cycle for curriculum change in order to respond to changing technologies.
- Fresh approaches to education could include new and more flexible modalities. Lifelong learning, self-learning, peer-learning and customised learning could be to be more pronounced.
- School curricula should steer away from machine-like tasks (memorisation, repetition, routine) towards human traits that machines are unlikely to replicate (empathy, creativity, innovation, social skills). At the same time, new technologies hold the potential for greater inclusion in school curricula, for example the inclusion of coding, 3D printing, and robotics.
- The use of technology for education requires increasing connectivity, as well as technological upgrading. All technological upgrading requires capability-building – we aim to avoid the installation of laboratories or other facilities without developing the capabilities to operate them.
- At the post-school level, curricula could be more multi-disciplinary – for example engineering students should engage with social science concepts, and vice versa.

Research, Development, and Innovation (RDI)

Building RDI capabilities is strategically central. Without the strengthening of innovation systems and RDI capabilities, South Africa will not be positioned to move towards the technological frontier, enhance competitiveness, or harness the technology towards developmental aims. RDI policy could include increased support directed through existing instruments, such as research chairs, centres of excellence, the National Research Foundation, and research programmes within universities and science councils. New instruments and mechanisms may also be considered. The DST has proposed the establishment of a 'Converging Technologies Platform' (CTP) as a potential hub for 4IR RDI. The CTP would be guided by a policy advisory service, the 'Inclusive Development Platform' (IDP). In addition, the DST has proposed the establishment of '4IR outreach centres' to engage with the public and disseminate information about research and development activities.

Standards and norms

A national policy framework could interrogate existing standards, norms and legal frameworks, in order to align with international standards to allow interoperability and collaboration, as well as facilitate the establishment of legal frameworks that would operationalise policy direction.

Public sector innovation

The technologies of the 4IR could be harnessed to strengthen the capacity of government to provide service delivery. This requires the building of internal government capabilities across a range of technological domains, including the use of AI and blockchain in governance, as well as the use of 4IR technologies to deliver services as diverse as health, security, sanitation, housing, environmental protection, economic development, and education, among many others.

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Smart cities and human settlements

A national policy framework could provide guidelines for unique programmes within South Africa's metropolitan areas, as well as for non-metro human settlements. A national policy framework could make provision for devolved policy-making, while at the same time establishing a mechanisms for the managers and strategic actors involved at the city level to interact, develop cohesive programmes, and foster mutual learning.

2.d. Towards developmental outcomes

Human development

The 4IR has the potential to be steered towards the improvement of human development in South Africa. This entails a focus on technology applications that improve human development. No list of such applications can be exhaustive, due to the diversity of technologies and of human development needs. Rather, this is a cross-cutting principle that applies to the leveraging of technological change, the building of technological capabilities, and the building of economic competitiveness and employment. An orientation towards human development is therefore a major cross-cutting function of the Framework.

Economic competitiveness

Building capabilities through education and RDI is a prerequisite for national economic competitiveness. Industrial and economic development policy options include incentives, SME programmes, and incubators. Some countries, for example Italy, have introduced a R&D tax incentive for industry 4.0 start-ups. A tax deduction related to training and skills development is an option. Digital innovation hubs, technology incubators, and SME development programmes all have the potential to support new businesses and SMEs. Incubators could be domain specific (e.g. AI incubator, ecommerce incubator, 3D printing incubator) or converged (e.g. 3D bioprinting incubator).

The future of work

The future of work is changing, and South Africa needs to respond. The International Labour Organisation (ILO) has formulated a consensus position on the future of work that frames it, in terms of values, as a fundamentally human-centric arena (ILO, 2019). Key elements of this position include foci on human capabilities, the institutions of work, and investment in decent and sustainable work. These focus areas present key tasks for South Africa has it negotiates current and future changes in the world of work.

Assessing the potential for automation-induced job losses, and mitigating their impacts, is an important component of a policy response. This imperative cuts across many policy arenas and government departments, and will have distinct dynamics in different sectors and industries. One general objective is the balance the need for technological upgrading, and therefore economic competitiveness, with the need for decent work and the prevention of unemployment

3. Structures for consultation and co-ordination:

Any national policy framework on the 4IR would require broad and ongoing social engagement. Germany's Platform Industry 4.0 may provide insights for how to structure such spaces. The policy options put forward in this framework have the potential to inform the debates within such spaces for engagement. The Presidential Advisory Commission on the 4IR has emerged as the strategic centre for policy formation. Related structures could include mechanisms for public engagement, meso-level structures within government, and strengthened international partnerships. Within this ambit, it is important to build a space where the DST, DTI, DHET, DTPS, and other interested departments can co-ordinate their respective policies and strategies, and align these with the national process. A 4IR Framework may include the development of functions focussed on facilitating policy alignment, for example the alignment of department-led data policy, Industry 4.0 policy, RDI policy, and skills development policy, as well as cross cutting policy areas such as artificial intelligence, economic development, and human development. The Presidential Advisory Commission will play a leading role in determining how to advance from a general framework to sectoral responses, including the role of stakeholders contributing to specific policies.

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1. Background

The Fourth Industrial Revolution (4IR) has been described as the fourth major industrial era since the initial Industrial Revolution of the 18th century, in which new technologies are fusing the physical, digital and biological worlds, and impacting all disciplines, economies, and industries (Schwab, 2016).

Key technology platforms include artificial intelligence (AI), robotics, the Internet of Things, autonomous vehicles, additive manufacturing (also known as 3D printing), quantum computing and nanotechnology, amongst others. The Fourth Industrial Revolution builds on the Digital Revolution, representing new ways in which technology becomes embedded within societies and the human body. The 4IR is seen as significant, imminent, and global. Being prepared for the 4IR means to position institutions in a way that the 4IR is harnessed for the benefit of human wellbeing, and in support of national and international social and economic objectives.

There are, and will continue to be, large-scale disruptions to the *production of goods and services:* Industrial automation, digitalisation, and services automation mean that machines increasingly compete with humans in labour markets.

Humans, both individually and socially, are also changing. Notions of the human, and human interaction, are undergoing multiple changes: increased longevity, augmentation of human bodies and minds, the changing nature of work, the changing nature of learning, changes to human connection and connectivity, and changes to identities, amongst others. Societies must confront growing inequality, and its interplay with unequal access to, and benefits from, technology.

At the same time, technological change is driving *geopolitical change*. New technologies are important to the future of power, and in some cases pose existential risks to humanity. For example, artificial intelligence (driven by machine learning technologies) is being used by geopolitical actors to gain power in the military, intelligence, economic, and public sphere arenas. At the same time, such technologies may pose global existential risks (for example, from rogue autonomous AI).

Within the 4IR it is critical that we put in place strategic measures that will prepare us: for example building innovation capacity, developing policy, writing legislation and regulations, joining multilateral and international agreements, and debating the ethics. The velocity of the 4IR suggests that by the time the policy cycle has turned, the 4IR may already have had an enormous impact – hence the urgency and significance of initiating policy cycles at all levels to respond to the 4IR.

2. Conference Overview

The South Africa – European Union Strategic Partnership Dialogue Conference on *Disruptive technologies and public policy in the age of the Fourth Industrial Revolution* was conceptualised as a response to an identified need for international multi-stakeholder engagement with a focus on the 4IR, at a time when South Africa's response to disruptive technological change was emerging as an increasingly significant national focus.

The conference programme, and speaker biographies, are presented in Addendum P2. A full transcript of the proceedings is available in Addendums A1, A2 and A3[2]. Participating speakers included leading academics, private sector executives, technology domain specialists, and senior public officials.

The Framework summarises and organises the key ideas and discussions emerging from the Dialogue conference, and therefore represents a synthesis of the collective insights of the 36 conference speakers, the 12 members of the steering committee, the supporting teams from the DST, HSRC, and EU Delegation to South Africa, and the over 100 conference delegates over three days of intensive discussion and debate[3].

[2] The full set of conference presentations is also available on request from the author
[3] Not all policy options emerging from the conference are referenced to the conference transcripts (Addendums A1, A2, and A3), but selected conference speakers are quoted where appropriate

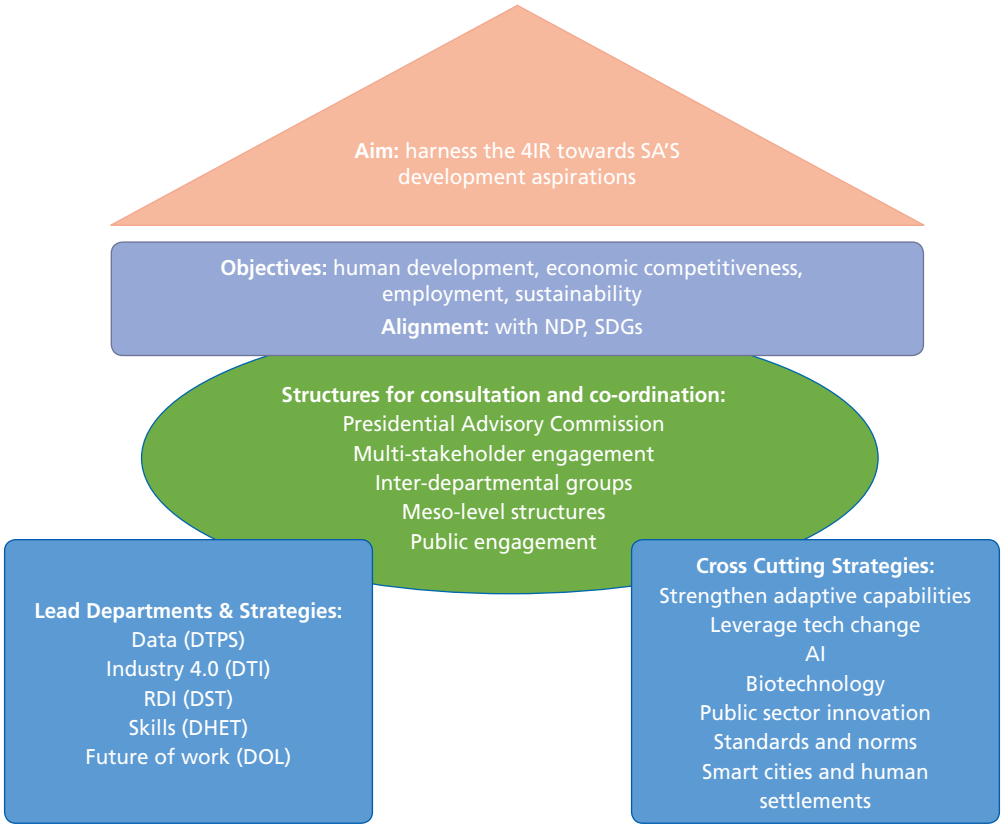
3. Framework 0verview

The purpose of a national Fourth Industrial Revolution (4IR) policy framework is to harness the power of the 4IR towards the achievement of South Africa's developmental aspirations. The Framework presented here consists of a proposed set of aims, objectives, structures, and strategies.

A 4IR policy framework needs to provide guidance for policy makers in all spheres to build evidence-informed, responsive and future-oriented policy. Due to the broad and cross-cutting nature of the 4IR, no framework can be exhaustive in its assessment of the potential applications of technologies, or its assessment of the human development roles these technologies might play.

We therefore need to support the development of functions within policy-making structures to make such determinations independently. Adaptiveness is indeed an imperative which intersects with the full technological and developmental scope of the Framework, and should be a consideration in the development of all policy mechanisms and interventions.

Figure 2: abstract of a national 4IR policy options framework



3. Framework 0verview

continued

1. *Alignment with values and policy* informs the framework's **aims, objectives,** and **alignment**. To steer the 4IR correctly, policy must be aligned with our developmental goals, for example as articulated in the NDP, and as expressed in the SDGs. There must also be alignment between departmental policies (e.g. of the DTI, DST, DHET, and DTPS).
2. *Strategic focus areas* inform **cross-cutting strategies**, as well as **strategies led by specific government departments**:
    a. Adaptive capabilities: Rapid and accelerating technological change is a central proposition of the 4IR concept. We therefore need a focus on responsiveness and adaptability, both as a policy objective in a variety of domains (e.g. labour markets, innovation systems) and as a characteristic of policy mechanisms that need to function effectively in a context of rapidly changing technologies and social dynamics.
    b. Leverage technological change: Technologies that are currently causing widespread disruption, for example AI, IIOT, genetic medicine, robotics, 3D printing, etc, should be focal areas in the contemporary policy landscape. The Framework explores means to leverage specific technologies – for example reducing data costs to make digitalisation more equitable, accelerating the adoption of machine learning by promoting the use of off-the-shelf systems, and streamlining the regulatory environment for genetic modification, etc. However, this focus will need to change over time, as existing technologies plateau, and new ones emerge to cause as yet unimagined disruptions. The technological scope that informed the 2016 concept of the 4IR has already shifted. We need to continuously monitor technological change in order to inform both research and policy.
    c. Build 4IR capabilities: building national capabilities is a prerequisite if we are to effectively harness the 4IR towards our developmental aims. Key areas of capability include our systems of innovation, our education system, the organs of state, and the strengthening of standards, norms, and legal frameworks.
    d. Towards developmental outcomes: our development goals, and the manner in which they intersect with the full technological scope of the 4IR, create a framework for us to define the desired outcomes of 4IR policy. Some examples here include:
        i. Human development
        ii. Economic competitiveness
        iii. The future of work
        iv. Transforming human settlements and working towards smart cities
3. ***Structures for consultation and co-ordination***: the Presidential Advisory Commission on the 4IR has emerged as the strategic centre for policy formation. Related structures could include mechanisms for public engagement, meso-level structures within government, and strengthened international partnerships.

4. Values and Policy Alignment

> ***"If 4IR technologies are not carefully steered it can really take us to a future where socio-economic challenges are exacerbated."***
>
> *~ Dr Erika Kreamer-Mbula*
> *SARCHi Chair in the 4IR, University of Johannesburg*

A national policy framework for the 4IR should be aligned to the objectives of the National Development Plan (NDP). Alignment could also be sought with the objectives of the United Nations Sustainable Development Goals, which place sustainable and inclusive human development at the centre of the agenda. A focus on sustainability raises questions about policy related to carbon neutrality, adapting to climate change, recycling e-waste, and moving towards a circular economy.

A national policy framework should also seek alignment with departmental strategies. Parallel processes within several government departments are under way to respond to the 4IR. A forum in which these processes can be aligned may benefit the final coherence of the policy response. Examples of departmental approaches, either complete or under development, include, amongst others:

- DTI: Digital Industrial Policy; Industrial Development Action Plan; Automotive industry master plan 2035
- DST: Converging technologies platform; inclusive development platform; 4IR outreach centres
- DTPS: Digital Transformation Centre

4.1. The Ethics of the 4IR

The 4IR raises a number of ethical questions for consideration, including questions related to data privacy, responsibility for autonomous drones and vehicles, the bioethics of genetic modification, and the societal and developmental impacts of social media and internet use on individuals and populations. Each of these issues requires ongoing engagement among stakeholders and a research response from South African universities and science councils, in order to inform the policy development process in an ethical manner.

4.2. The Meaning and Language of the 4IR

A national policy framework would need to address the semantics of the 4IR. Words have power, and demand consideration. We need to think about how South Africa, as a nation, describes the phenomena of the 4IR. Using the term 'fourth industrial revolution' aligns with the conceptualisation of the World Economic Forum (WEF). At the same time, use of the term may be seen to imply uncritical adoption of a WEF position. A national policy framework should be preceded by, and include, ongoing dialogue over the language of the 4IR, and how it might best be framed in the South African public sphere. It may be the case that, like other countries (see Figure 3), South Africa coins its own term to describe its contextualised approach to accelerating technological change and technological disruption.

4. Values and Policy Alignment

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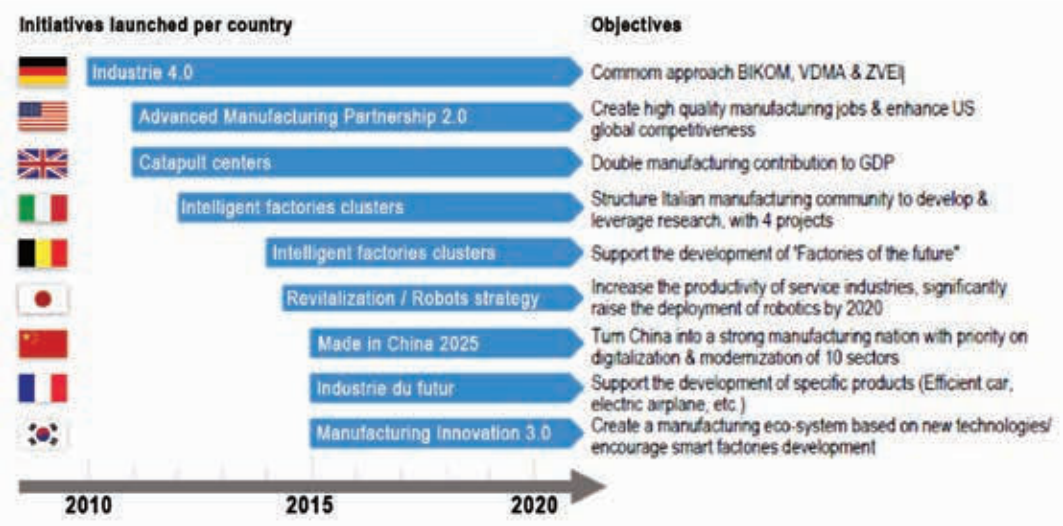
Figure 3: National strategies aligned to the 4IR *Source: Roland Berger, World Economic Forum*



4.3. The Transformation Imperative

> ***"The 4IR allows us to modernise the public sector with economic inclusion and development of black entrepreneurs at the centre of our policy formulating and implementing. We can't change the past, but we can influence the future. We can give hope to young upcoming black entrepreneurs so they too can build through skill, merit and hard work. All we ask for is a stepladder to climb."***
>
> *Mr Tilson Manyoni: Head of Policy, Black Business Council*

The 4IR can't leave black South Africans behind, or it will become a force for social instability and historical injustice. Transformation will be central to any South African policy framework for the 4IR. The 4IR has the potential to generate new opportunities for black participation in the formal economy, for the emergence of black industrialists, and for new opportunities for growth and livelihoods in the informal sector.

From an African perspective, the deeper historical significance of this moment should not be forgotten. During the first industrial revolution, Africa was suffering at the hands of the slave trade. During the second industrial revolution, Africa was being colonised and partitioned.

During the third industrial revolution, the early period of decolonisation had led to the emergence of proxy governments, dictatorships, conflicts, and instability. Following this historical analysis, we can conclude that if Africa does not position itself to join the fourth industrial revolution it will remain at the margins of the global development process. South Africa, as the continent's most technologically advanced and most industrialised nation, therefore has a collective responsibility to lead Africa into the fourth industrial revolution.

A mindset of catch-up or imitation is to be avoided. Africa, as a collective, has the same right and responsibility to strive for excellence as any other global region. South Africa must take an aspirational view, and aim to be at the cutting edge of technological change. Any other view would be defeatist, send an inappropriate signal of intent, and fail to guide policy correctly.

> ***"The question is not about how we embrace the technology of 4IR development, it's how we become at the cutting edge of it. We don't have to respond to it, we must be part of the creation of it and own it rather then get other people to do it."***
>
> *Rev Frank Chikane: Chairman, Kagiso Trust*

4. Values and Policy Alignment

continued

4.4. Technological Change and Inclusive Development

> ***"There has been a hard won recognition of the importance of innovation for inclusive development. We need to link that very tightly to discussions around the 4IR. We need to not only think about how you make commercially viable businesses, but how you make businesses that are viable for everyday livelihoods. We have millions of South Africans who are making livelihoods in precarious ways, and we could be harnessing these technologies of smart phones etc. to enhance their livelihoods, and then we are developing the whole of South Africa and creating a competitive South Africa in that sense."***
>
> *(Dr Glenda Kruss, Deputy Executive Director: Centre of Science, Technology, and Innovation Indicators, Human Sciences Research Council).*

The question of transformation includes the issue of inequality. Tackling inequality is central aim. In this regard, both the process and the outcomes of the strategy need to be inclusive. Building inclusivity faces multiple headwinds. Automation has the potential to increase unemployment among unskilled and low-skilled workers, while benefitting the highly skilled. The digital divide has the potential to accelerate existing drivers of inequality. Advances in health care might only be available to the rich and middle classes, thus exacerbating health inequality. Indeed, the pervasiveness of inequality, and the widespread systemic risks of inequality arising from technological change, imply that the principle of inclusivity should be built into every policy decision, and applied across the 4IR's technological and thematic scope.

For policy that aims to leverage 4IR technologies for inclusive development, the path may include:

- Leading a healthy and critical dialogue around equitable and inclusive deployment of new technologies
- Fostering the design of policies and regulations that enable inclusive and rights-based use of technologies
- Catalysing the development of inclusive and ethical applications.
- Building the infrastructure and skills for inclusive and ethical applications – for example support programmes in government, and studies of social benefits and risks.

5. Adaptive Policy in an era of Technological Revolution

> ***"We need to be mindful of challenges, because in a way they are qualitatively different. We are having far move waves of change at far shorter intervals."***
>
> ***~ Prof Brian Armstrong***
> *WBS/Telkom Chair in Digital Business at the Wits Business School*

It is important to recognise that it is challenging to develop a policy framework for an extended time period in an environment of rapid technological change. Yet this is necessary to cultivate investment confidence and policy certainty. Building responsiveness and adaptability into a dynamic policy framework is therefore critical.

The essence of the 4IR is not about any particular technology, or group of technologies. The 4IR is not about robotics or artificial intelligence or regenerative medicine *per se*. It is about technological change as a broad and accelerating process. The publication of the book, 'The Fourth Industrial Revolution' (Schwab, 2016) presented a conceptualisation of accelerating and converging technological change, combined with a movement towards transhumanism, that was focussed on technologies that were breaking new ground in 2015. Even in the short time since then, the technological landscape has shifted. In ten years' time a new set of ground-breaking technologies will be altering the course of social and economic trajectories – possibly technologies we can't identify yet.

The core of any national response to the 4IR must be an increased capacity to be responsive to technological change - to sense changes in the global and local technological environments and to interpret these changes in terms of their relevance to economies, society, institutions, and policy. This intelligence must be systematically used to inform a coherent and dynamic policy cycle. It is imperative to remain flexible, since by the time the policy cycle has turned, it is likely that new technological dynamics will be at play. While contemporary policy must indeed seek to leverage specific technologies such as artificial intelligence, additive manufacturing (3D printing), and the industrial internet of things, it must also develop the overall adaptive capabilities of systems to harness and steer technological change towards meeting developmental agendas – for example by strengthening the capabilities of universities and firms to interact and exchange information about future skills demand and supply, or by developing intelligence about frontier technologies in order to inform future-oriented policy.

5.1. Research capacity for adaptive policy

An adaptive policy model requires ongoing intelligence, emerging from a focussed policy research agenda. Firstly, rapid technological change creates a requirement for ongoing assessment and review of the technological scope of the 4IR. Technologies that are currently leading the way may continue to revolutionise economies and societies, but their influence may also plateau as they give way to newly emergent technologies that are not yet on the policy radar. It is therefore necessary to strengthen research capacities for sensing and making sense of changes at the technological frontier, and internalizing this intelligence into an ongoing and adaptive policy cycle. We have termed this a 'Frontier Technology Observatory' function.

To guide its 4IR Research, Development, and Innovation policy, the DST has proposed a dedicated policy research centre, the Inclusive Development Platform (IDP). The IDP would establish multifaceted intelligence systems related to disruptive technologies, including their related innovation systems, sectors, value chains, and city-regions.

5. Adaptive Policy in an era of Technological Revolution *continued*

We need to understand the impacts on production, consumption, trade, investment, employment, skills requirements, R&D, innovation, and regulation, amongst other areas.

South Africa has not as yet commissioned a detailed empirical assessment of the future of work, and this would form a critical part of the overall research component of the 4IR policy framework. Moreover, any empirical economic and technological study should be supported by sociological analysis that interrogates work as a social structure and political arena.

Specific elements of the policy research agenda include:

- Modelling the economic impact of changes to South African innovation systems
- Analysis of the interactions between innovation systems and labour markets, including research into innovation systems and skills supply and demand in advanced technology domains.
- Future studies approaches and scenario planning
- Multi-disciplinary social science focused on the human and social impact of technological changes
- Studies of innovation for inclusive development, which could inform the steering of technological change towards equitable outcomes.
- Policy research will require the measurement of innovation. The HSRC's Centre for Science Technology and Innovation Indicators (CESTII) is exploring ways to integrate new technologies into the national R&D and innovation surveys.

Research questions in the terms of reference of the Presidential Advisory Commission on the 4IR:

- How should South Africa characterize the 4th Industrial Revolution in regard to its social and economic aspirations and priorities?
- What is South Africa's state of readiness towards the Fourth Industrial Revolution? What are South Africa's unique competitive advantages (local and international) in these areas: developments in Internet of Things, genetics, artificial intelligence, robotics, nanotechnology, 3D printing and biotechnology?
- What will be the impact of the Fourth Industrial Revolution on government, business and society as a whole?
- What are the opportunities and threats presented by the Fourth Industrial Revolution?
- Does South Africa have adequate skills for the Fourth Industrial Revolution, if so, in which areas, and where are the gaps as well as the skills that will be required going forward?
- How do we prepare the workforce for multiple career changes that cut across occupational boundaries?
- What are South Africa's Research and Development (R&D) capabilities to support the Fourth Industrial Revolution?
- What technologies should be manufactured locally to grow the ICT and related 4IR industries?
- What strategies are needed to ensure the uptake and usage of ICTs and other 4IR technologies in other sectors of the economy to drive innovation, SMME participation and job creation?
- What are the likely unintended consequences (such as job losses) and how to mitigate them?
- What mechanisms are needed to ensure effective coordination and collaboration amongst all stakeholders?

6. Leveraging Technological Change

The 4IR, as conceived by the World Economic Forum in 2016, is to some extent defined by contemporary transformative technologies, such as artificial intelligence, robotics, and genetic modification.

The 4IR diagnostic is underpinned by some central propositions that apply to these technologies, including:

- Convergence: digital, physical, and biological technologies are becoming increasingly integrated and blurring the lines between these three spaces.
- Acceleration: the overall rate of technological change is increasing over time. The absolute rate of technological change is hence increasing exponentially.
- Transhumanism: due to convergence and acceleration, the boundaries of what can be considered to be 'human' are and will continue to expand significantly, including into new physical, digital, and biological spaces.

Each technology, and each converged application of technologies, presents a distinct set of policy imperatives and opportunities, and hence forms a distinct component of the overall Framework. Establishing strategies to steer these technologies towards our desired developmental outcomes is a central component of the Framework. Some strategies may be clearly identified with lead departments, some of which are already developing strategic responses. For example, the DTI is leading Industry 4.0 strategy, the DTPS leading digital strategy, and the DST leading Research, Development and Innovation (RDI) strategy. Other technology strategies are 'horizontal', in that each technology cuts across a number of social and economic dimensions and the remits of several government departments. For example, AI, as a technology, is both a policy domain in itself, and a technology that can be brought to bear on issues of education, skills development, the future of work, economic competitiveness, and governance, amongst other areas.

6.1. Digitalisation and the Data Revolution

'Digitalisation' refers to digital processes replacing or supplementing processes that were previously not digital. Classic examples are the growth of online retail, sharing systems such as Uber and AirBnB, and the replacement of legacy media with online media. Digitalisation therefore encompasses many of the major economic and social disruptions of the last two decades.

Disruptive technologies that are shaping digitalisation trajectories include:

- Augmented and virtual reality
- Big data and data analytics
- Cloud computing
- Human/machine interfaces
- Data monetization

In South Africa, the Department of Postal Services and Telecommunications is leading national policy formulation in response to the digital revolution.

Of critical importance to the national response to digital disruption is a deeper understanding of its causes and dynamics. Here the work of Prof Brian Armstrong (WBS/Telkom Chair in Digital Business at Wits Business School) provides useful frameworks and insights. By disaggregating the root causes of digital disruption, Armstrong's analysis provides a point of departure for targeted policy interventions to either mitigate negative consequences or grasp the opportunities provided by digitalisation (Armstrong, 2019).

It is perhaps not hyperbolic to describe data as the 'new gold' or 'new oil' of the twenty-first century. It is certainly central to the 4IR, as it underpins the technological dynamics of AI, digitalisation, Industry 4.0, genetic medicine, and many other contemporary technologies. A national policy framework for the 4IR must address the issue of data, including the questions of data protection and data access.

6. Leveraging Technological Change

continued

Data Protection and Privacy

The right to privacy in South Africa is enshrined in the Section 14 of the South African constitution, and Act 108 of the 1996 Bill of Rights, which provides for the right for all South Africans to not have the privacy of their communications enfringed. An individual's right to privacy 'safeguards an undisturbed private life and offers the individual control from intrusion into ones private sphere' (Cuijpers, 2007).

The current legislative framework for data protection is the Protection of Personal Information Act (POPIA), which aims to protect the processing or accessing of personal information, such that responsible parties or data controls do not infringe on the right to privacy while chasing business objectives, or analysing trends in big data. The act is South Africa's equivalent of Europe's GDPR (General Data Protection Regulation). POPIA is intended to protect South African citizens but, importantly, it also provides assurance to international players that SA follows international best practice and that it is safe to conduct business within our borders. POPIA is regulated by an independent Information Regulator. However, the Information Regulator may currently be under-resourced: it currently is staffed by only a a chairperson, two full time members, and two part-time members. Increased capacity at the Information Regulator may be a necessary intervention, given the centrality of data, and the multi-dimensional issue of data privacy.

One data privacy issue is that of international consumption, and indeed monetisation, of South African data:

> ***"What is happening with data which we are putting into social networks or whatever data? If you want personalized medicine we need to share our health data, our personal medical data. Are we going to share our data with a platform that is based in US or China?"***
>
> *Prof Vladimir Sucha: Director-General, Joint Research Centre, European Commission*

There is also a tension between the imperative of open data and the imperative of data privacy. Achieving a balance between these two opposing principles is arguably central to an overall approach to data policy.

> ***"We actually have two laws that go in opposite directions. The force going into access to information vs the force vs privacy of data. There is a lot of space to exploit data and to make money out of it. The issue is not where to but the how, to do it in a legally ethical manner, in a way that data is not abused."***
>
> *Mr Sizwe Snail Ka Mtuze, Information Regulator*

Data Access and Data Inequality

Connectivity is a crucial means of levelling the playing field for South Africa's youth, and connecting populations that are geographically isolated and/or marginalised. However, South Africa has yet to provide an environment that supports data equality:

> ***"The problem in South Africa isn't the average cost of data; the problem is the entry level packages. If you by a Vodacom 10 meg package you will be paying 80c – 90c per meg. If you by a MTN 20 meg package you paying 60c per meg. The problem isn't the average prices, it's the entry level prices, [which] are so critical for the people in our market who can't afford 200 gigs and 400 gigs or uncapped to link. There is always an issue around the more you buy the more you get, but it can't be 100 fold difference."***
>
> *Prof Brian Armstrong, WBS/Telkom Chair in Digital Business at Wits Business School*

6. Leveraging Technological Change

continued

Poor people pay far more for their data than the middle class. We need to develop measures to reduce the cost of data for the poor. One aspect of the solution is the allocation of spectrum to data providers. Another solution is that of revisiting the question of competition in the sector, and the relationship between firms and regulators. Finally, there is the potential for government to engage directly with South African data providers with the aim of restructuring their tariff rates to reduce the large difference between data costs for the poor and for the middle class.

Without access to data, citizens simply can't participate in the 4IR. Without data, citizens are left on the wrong side of the digital divide. Without access to the internet, students and learners suffer from a vast gap in access to information and knowledge, entrepreneurs lack access to broader markets, and innovation systems in marginalised and informal settings are continuously hampered. If the digital divide is placed at the centre of our analysis, the question of data costs for poor people in South African might indeed by the most critical issue in the overall national response to the 4IR.

5G

The fifth generation of mobile communications, or 5G, promises high speed, low latency and high bandwidth – and is seen as a significant enabler of the Internet of Things (IoT), virtual reality (VR) and robotics. A key feature of 5G, splicing, allows the creation of sub-networks that accommodates a variety of needs across different consumer and business groups. For example, Germany has reserved a quarter of 5G bandwidth or local and regional applications to enable businesses in the industrial and agricultural sectors, as part of the country's Industrie 4.0 strategy. This data policy creates an environment in which the Industrial Internet of Things operates in a data environment in which the complex cyber-physical systems which underpin Industry 4.0 can function effectively. A national 4IR data policy would need to take a decision on the question of 5G splicing, taking into account questions of data access and questions of enabling Industry 4.0 in South Africa.

Digital Sovereignty

> ***"We don't need to redistribute from Sandton to Soweto, we need to redistribute from Silicone Valley and Shanghai to Soweto. The challenge is how do we stop being a digital colony and become a digital republic?"***
>
> *Prof Brian Armstrong, WBS/Telkom Chair in Digital Business at Wits Business School*

In a world where data is a driving force of multiple social and economic processes, South Africa cannot afford to be a 'digital colony', in which citizens and institutions produce data that is shipped offshore for processing and monetisation. This logic suggests that the South African government should, like other governments, engage with Silicon Valley tech giants – arguably the main beneficiaries of the monetisation of South African data – in negotiations that would aim to support data sovereignty and internalise the beneficiation of South African data, while at the same time adhering to the principles of free markets and connection to the global digital economy.

It should not be the case that most South African data passes through infrastructure systems over which the country does not have sovereignty. It may therefore be appropriate to explore the potential for South African to launch its own communication satellites into space. All South African data passing through space currently is processed by satellites that are launched in other countries, and in almost all cases are processed by satellites that are developed and built in other countries. This creates a weak data sovereignty position for South Africa, including in the domains of the military, intelligence, public sector, and commercial applications.

6. Leveraging Technological Change

continued

Cyber Security

The cyber-security threat landscape includes 'anonymous' hackers, organised criminals, foreign intelligence operatives, 'insider' operatives working from within institutions, and international terrorist groups. Enhancing cyber-security is important in the context of the 4IR. In principle, this significance is based on the large and growing role of data. In practice, the tools of cyber criminals and cyber security now include artificial intelligence systems. The integration of artificial intelligence into South Africa's cyber security systems is therefore imperative.

Financial Systems

> ***"We were disrupting financial services via feature phones providing financial services to the unbanked. We were just using mobile network operator data, wallet behaviour, building our credit risk history. In the African, not only formal environments, you can reach the unbanked and provide the state of the art solution."***
>
> *Dr Jacques Ludik, CEO: Cortex Logic*

Ongoing review of the impact of the 4IR in the financial sector is needed in order to safeguard financial stability. Financial systems face at least three major disruptions: crypto-assets, AI trading, and new payment technologies. New payment technologies have the potential to include greater proportions of marginsalised populations into the financial systems. AI trading is creating occasional instability in financial markets.

The SA Reserve Bank has created a task team to engage with the question of crypto-assets. The Reserve Bank is also in the process of reviewing the national payments system and the Act – in particular looking at opening up the process to third party payment providers and APIs in line with the EU standard of PSD2.

6.2. Data and AI

> ***"Data is the new gold of the 21st century"***
>
> *Prof Vladimir Sucha: Director-General, Joint Research Centre, European Commission*

If data is indeed the new gold of the 21st century, then artificial intelligence is our main tool for mining and processing. Artificial intelligence can be defined as a machine or man-made agent capable of observing its environment, learning, and based on the knowledge and experience gained, taking intelligent action or proposing a decision. The global literature addressing the AI phenomenon has grown rapidly in recent years, providing rich resources for the development of AI-related policy.

National AI strategies are being developed in many countries, including the USA, China, Italy, Germany, the UK, Japan, and many others. Within the overall ambit of a 4IR strategy, a dedicated national AI strategy is essential. Moreover, it is critical that a national AI strategy be aligned with and integrated with a national 4IR strategy. AI strategy includes many components and logics similar to a 4IR strategy, including the need to build skills and broad-spectrum RDI, stimulate investment, set legal and regulatory frameworks, address ethical issues, build public awareness, and seek applications that meets developmental aims.

At an operational level, one of the key messages delivered by AI leaders and practitioners is that the technological fundamentals of machine learning applications to not have to be developed *de novo* – off-the-shelf machine learning systems are freely available from multiple vendors, including Google, Amazon, and Microsoft, amongst others. When building capabilities, South Africa therefore needs to strike a balance between building advanced scientific capabilities in the AI domain, and building technological capabilities in the domain of AI applications. It may be the case that stimulating the use of off-the-shelf machine learning systems is the best option for accelerating the

deployment of artificial intelligence applications in South Africa.

6.3. The future of manufacturing and Industry 4.0

Manufacturing has the potential to play a greater role in the South African economy, but to do so the sector must grapple with increasing complexity and technological disruption, while also addressing transformation imperatives.

Industry 4.0 is a concept, originating in Germany, that focusses on production automation through the use of cyber-physical systems and advanced manufacturing technologies (Kegel, 2019). The concept of Industry 4.0 overlaps with, but is distinct from, the notion of the 4IR. While Industry 4.0 has a production focus, the notion of the 4IR has a broader global socio-political component that considers in more depth the interplay between technological change and social change.

Industry 4.0 is central to changes in manufacturing in the 4IR. These changes include the integration of several of the core 4IR technologies, including:

- Big data and data analytics
- Autonomous and collaborative robots
- Simulations (of products, materials, and production)
- Horizontal and vertical systems integration
- Industrial internet of things
- Cloud computing
- Additive manufacturing (also known as 3D printing)
- Human-machine interfaces

Central to industry 4.0 is the use of cyber-physical systems, including the integration of the industrial internet of things (IIOT) into the manufacturing environment. Typical changes in the shift towards Industry 4.0 include:

- Process-driven operations to data driven operations
- Preventative repairs to predictive repairs
- Cyber systems and physical systems to cyber-physical systems

In South Africa, Industry 4.0 policy is spearheaded by the Department of Trade and Industry, where a dedicated 4IR directorate has been established, and policy formulation is in progress at the time of writing. Industry 4.0 policy must be integrated with data policy, due to its reliance on a permanently connected network of devices and equipment. In this regard, the option of 'splicing' 5G bandwidth is both a question of data policy (to be led by the DTPS) and a question of industry 4.0 policy (to be led by the DTI). It is also a question of capability building (to be led by the DHET) and innovation (to be led by the DST). Industry 4.0 thus forms a major component of an integrated 4IR national policy framework.

A policy framework for industry 4.0 should perhaps be sector specific, since the manifestation of industry 4.0 has distinct characteristics in each sector. Two case studies, from mining and automotive manufacturing respectively, illustrate these distinctions.

Case study: Mining Sector

Industry 4.0, and the broader 4IR environment, are critical strategic factors for the mining sector. In its assessment of the top ten business risks to the mining sector (Verhaege, 2019), the Mandela Mining Precinct identified digital effectiveness (ranked 2), cyber security (ranked 4), the future of the work force (ranked 7), and disruption (ranked 8) within its major risk assessment. The number one risk was 'licence to operate', which refers to the position of mines in the public sphere. This risk is in turn intrinsically linked to the questions of automation and its potential impacts on employment.

In order to remain competitive, the mining sector needs greater capabilities in the areas of data-driven processes and technologies, data-driven decision making, future-proof design, and open systems. This needs to be accompanied by quality skills development. At the same time, cost reduction is important, as the mining industry operates on narrow margins.

6. Leveraging Technological Change

continued

Case study: Automotive Sector

> ***"Auto value-adding process will significantly change – how do we capture that value?"***
>
> *Dr Justin Barnes, Chairman: Benchmarking and Manufacturing Analysts*

The automotive sector plays an important role in South Africa's manufacturing economy and in the broader economy. It accounts for approximately 13% of manufacturing output, is the only manufacturing sector that has grown significantly in the last 20 years, and is responsible for building national capabilities that spill over into other manufacturing sectors. The automotive sector has consistently received policy support – one of the reasons for its continued survival in challenging conditions.

Key questions related to 4IR technologies include:

- How will the internet of things change mobility?
- How will 3D printing displace established global design and production value chains?
- How will the use of advanced materials change what vehicles are made of?
- What does artificial intelligence mean for the organization of value chains, skills, and labour requirements?
- What do robots and digital twins mean for future labour demand and skills requirements?

Globally, the automotive sector is experiencing a shift towards alternative powertrain technologies, including hybrid, electric, and fuel cell vehicles. At present it is unclear whether electric or fuel cell vehicles will come to dominate the market in the long term. At the same time, there have been major advances in internal combustion engine technology, challenging the transition towards alternative powertrain technologies. Internationally there is increasingly demanding end-of-life vehicle legislation, forcing recycling and minimizing waste. The advent of autonomous vehicles is poised to further disrupt the sector.

South Africa's response to these global changes will be critical to the future of the sector. Will South Africa be 'efficiency seeking' and aim to maximise return on investments in existing technological platforms, or will the sector in South Africa participate in the global value chain disruptions? There may ultimately be little choice. Sixty percent of South African production is destined for export markets. South Africa's vehicle assembly capabilities are tied to previous generation fuel and chassis technologies, which face the medium-term prospect of being phased out of developed country markets.

Throughout these processes, leading technologies will be controlled by multinationals – raising the question of how South Africa engages in global innovation networks. The high-level strategic question is about how South Africa can move to secure value-adding roles within the changing global environment.

6.4. Biotechnology

> ***"The scale of information really makes biology a data science- 3 terabytes of information in 37 trillion cells… Precision medicine has become a big data science."***
>
> *Prof Musa Mhlanga: Molecular and Cell Biology, University of Cape Town*

Biotechnology plays a large and growing role in health and agriculture. Of particular importance is the CRISPR technology for low-cost precision gene editing. Extant applications of CRISPR include the development of virus-resistant crops (e.g. cassava), delayed ripening (e.g. of tomatoes), and changes in appearance (e.g. non-browning mushrooms).

In the USA, CRISPR applications are exempt from the regulations that apply to other gene modification technologies, primarily because foreign DNA is not added during the process – instead existing DNA is deleted or edited. This regulatory

6. Leveraging Technological Change

continued

approach could be considered in South Africa, where CRISPR applications have the potential to benefit the agriculture and health sectors, but are currently hampered by high regulatory barriers and compliance costs.

The bottom-line logic of facilitating greater usage of CRISPR applications is that South Africa's population requires food security, and we therefore we need to lose less food due to drought, climate change and dread disease, and that gene editing can help improve production, decrease waste and make food more nutritious.

High regulatory costs create a barrier that prevent new GM technologies, developed within SA universities, from benefitting the public.

> ***"The problem is that the regulatory cost is so expensive that for any normal university research institute to get anything commercialized is almost beyond our financial capabilities. For example, we developed a maize seed virus resistant maize, in conjunction Panar, which is a seed company in KZN. It worked fantastically, but they said the cost is too high for us to commercialize by going through the glass houses and feeding trials. Panar went to Pioneer, who said this product is only going to be used in Africa. African farmers do not have money to fund the expenses of the regulation so I'm sorry. So the virus resistant maize is sitting in the fridge in my lab and Panar's lab."***
>
> *Prof Jennifer Thomson: Molecular and Cell Biology, University of Cape Town*

In health applications, South Africa has a responsibility to counter the consistent global bias in global genetic databases, which largely exclude African populations (even though African populations are the most genetically diverse in the world).

7. Building 4IR Capabilities

The ultimate purpose of a national 4IR policy framework is to steer the 4IR, across its technological scope, towards the achievement of South Africa's developmental aspirations, for example as expressed in the NDP.

Harnessing the benefits of the 4IR requires, in the first instance, the building of national capabilities. Economic competitiveness, economic growth, employment growth, and the ability to utilise 4IR technologies to achieve socially beneficial outcomes, all require the development of capabilities in the key areas of education and skills development, research and innovation, and public sector innovation.

7.1. Building capabilities through education and skills development

> ***"We cannot have a conversation around policy options for the future without putting young people at the center of our discussion."***
>
> *Dr Mlungisi Cele: Acting CEO, National Advisory Council on Innovation*

The questions of skills and work are central to the global and national responses to the 4IR. The overall reconceptualization of education must grapple with the issue of change: rapid technological change, economic change, social change, and changes in labour markets all require increased flexibility and adaptability.

Adapting to change requires an increased focus on the capacity of institutions to sense changes in their environments and adapt accordingly, a characteristic known as interactive capabilities (Van Tunzelman and Wang, 2007). This imperative motivates for increased intensity and effectiveness of communication and collaboration across systems of education, industry, civil society and government.

Strengthening the interactive capabilities among institutions of skills supply requires:

- Cultivating the capacity of post-school education institutions to engage with employers and understand their current and potential future skills requirements (which change along with technological change).
- Shortening the cycle for curriculum change in order to respond to changing technologies.
- Cultivating a research agenda that senses technological change and responds accordingly.

Strengthening the interactive capabilities among the institutions of skills demand requires:

- Strengthening platforms for the private sector to make sense of technological changes, and better understand how they might impact on their future skills requirements.
- Building and strengthening platforms for dialogue between employers and post-school education systems, to facilitate the exchange of information about the impact of technological on future skills demand.

Fresh approaches to education need to include new and more flexible modalities. **Lifelong learning** needs to be more pronounced in the policy mix.

> ***"It's not only about acquiring the degree which it will be essential, but there must be more space created for adults to continue their education and learn. Adaptive learning, micro learning, upskilling in different ways."***
>
> *Dr Erika Kraemer-Mbula: Associate Professor of Economics, University of Johannesburg*

Digitalisation of knowledge resources opens up opportunities for **self-learning**.

> ***"We should [do away with the idea] that all the kids have the same type of training in school. They have to have tailored education according to the wishes of the kids. Some countries have started investing in that type of education. With the 4IR there is no choice but to re-think the education system."***
>
> *Dr Brahim Ghribi, Head of Government Relations Middle East and Africa: Nokia*

7. Building 4IR Capabilities

continued

Self-learning on Youtube is already happening informally. But such 'self-directed learning' may itself require intervention:

> ***"Self-directed learning, it's great for people that have access and can use that technology. The majority of SA don't have access. Parents don't know how to guide the youngsters."***
>
> *Ms Laura Crosby: Manager: Labour market and sector skills planning, MERSETA*

School curricula should steer away from machine-like tasks (memorisation, repetition) towards human traits that machines are unlikely to replicate (empathy, creativity, innovation, social skills, managing complexity). At the same time, each of the 4IR's technologies hold the potential for greater inclusion in school curricula. The introduction of coding in schools is currently being piloted by the Department of Basic Education – an important feasibility study that is hoped will assess the enablers, constraints, and challenges associated with such a change. The establishment of 3D printing laboratories would benefit from a similar process.

Another dimension of 4IR education policy is the **use of technology for education**. Increasing connectivity is the first step, followed by technological upgrading. However, bringing connectivity to schools is not about establishing computer labs and internet access. It's about building the capability within the school to use and maintain the lab. This is a much greater challenge. A potential intervention could be a national programme with this specific focus.

At the **post-school** level, the logic of the 4IR suggests that curricula should be broader – engineering students should engage with social science concepts, and vice versa. In a world where complex socio-technical systems evolve rapidly and unpredictably, technology development should not be undertaken within an understanding of social context, and social analysis should not be undertaken without an understanding of technological dynamics. In higher education, it's critical to build curricula related to 4IR technologies, each of which has generated market signals that indicate a high level of employer demand. For example, advancing AI capabilities through education and skills development interventions is seen as critical, as the number of AI specialists is dwarfed by market demand for such expertise:

> ***"We have a huge fight for human resources. Very tiny layer of people capable of advancing AI."***
>
> *Prof Vladimir Sucha: Director-General, Joint Research Centre, European Commission.*

7.2. Building capabilities through research and development

> ***"We need to think about innovation differently, it's not only about technological innovation, it's also about grassroots innovation. It's also about scale, not only product and process innovation but complex products and systems."***
>
> *Mr Garth Williams, Research Specialist: Intelligence, Technology Innovation Agency.*

Building RDI capabilities across the technological scope of the 4IR is an important component of the Framework. This includes increased support through existing instruments, such as research chairs, centres of excellence, the National Research Foundation, and research programmes within universities and science councils.

To guide the establishment of an integrated Research, Development and Innovation (RDI) response, a view of the 4IR as a set of interlocked and evolving **systems of innovation** (Lundvall, 1992) needs to be maintained. Within South Africa's national system of innovation, sectoral systems of innovation underpin the capabilities and outputs relevant to each of the 4IR's technologies. Building capabilities through RDI will require healthy and well-functioning innovation systems, which requires paying attention to linkages and interactions, and the extent to which systems can

7. Building 4IR Capabilities

continued

adapt to rapid change. An important component of this analysis is the necessity for change to be inclusive, both in its process and in its outcomes.

The innovation system analysis shouldn't be restricted to the formal sector – we need to include informal settlements and the informal economy in the analysis. How are South Africans living in resource-constrained environments adopting and adapting technologies? This line of enquiry may lead to intervention pathways that leverage the capabilities vested in the informal sector, and may also provide ways to bolster the inclusiveness of our policies and interventions.

In South Africa, the Department of Science and Technology (DST) is leading the national 4IR response in the area of RDI. This leadership is aligned with the normative orientation of the DST's White Paper on Science, Technology and Innovation, which calls for 'STI enabling sustainable and inclusive development in a changing world'. The DST has proposed the establishment of a 'Converging Technologies Platform' (CTP). The CTP would aim to build deep capabilities in niche areas across various technology areas; integrate capabilities to support competitiveness and service delivery; deploy resources based on need and evidence; and enable partnerships with industry and government actors. The DST's Technology Innovation Agency (TIA) also has a potential role to play in supporting developmental uses of 4IR technologies, particularly in terms of crossing the gap between research and application.

The CTP would be guided by a policy advisory service, the 'Inclusive Development Platform' (IDP) that would provide policy, advisory and decision support to the CTP; include inter-disciplinary research teams and have a strong international orientation, but focussed towards a developing country agenda.

In addition, the DST has proposed the establishment of '4IR outreach centres', which would aim to equip and prepare the youth and SMEs for the 4IR, by leveraging existing outreach and engagement platforms.

The technologies of the 4IR may also be put to use in the social science research environment. For example, artificial intelligence may contribute to the development of economic modelling. The establishment of an African Research Cloud, which places public data on the cloud for use by researchers and entrepreneurs, may also have a catalytic effect.

7.3. Standards and norms

A national policy framework would need to interrogate existing standards, norms and legal frameworks, in order to align with international standards to allow interoperability and collaboration, as well as facilitate the establishment of legal frameworks that would operationalise policy direction.

7.4. Public sector innovation

The technologies of the 4IR could be harnessed to strengthen the capacity of government to provide service delivery. This requires the building of internal government capabilities across a range of technological domains, including the use of AI and blockchain in governance, as well as the use of 4IR technologies to deliver services as diverse as health, security, sanitation, housing, environmental protection, economic development, and education, among many others.

8. Social and Economic Outcomes: Towards a Developmental Agenda

Building 4IR capabilities is a means, but achieving South Africa's developmental aims is the purpose of 4IR policy.

Due to the broad and cross-cutting nature of the 4IR, no framework can be exhaustive in its assessment of the potential applications of 4IR technologies, or its assessment of the human development roles these technologies might play. Critical, then, is the development of functions within policy-making structures to make such determinations independently, and to operate independently, using the broader framework as a guideline.

8.1. Human Development

The 4IR must ultimately be steered towards the improvement of human development in South Africa. This entails a focus on applications of 4IR technologies that improve human development. No list of such applications can be exhaustive, due to the diversity of technologies and of human development needs. Rather, this is a cross-cutting principle that applies to the leveraging of technological change, the building of technological capabilities, and the building of economic competitiveness and employment.

8.2. Economic Competitiveness

Broadly, an integrated policy response to the 4IR is critical for national economic competitiveness, and for long-run employment prospects. Building capabilities through education and RDI is a prerequisite. Further policy options include incentives, SME programmes, and incubators.

Tax and Investment Incentives

Some countries, for example Italy, have introduced a R&D tax incentive for industry 4.0 start-ups. Another potential tax incentive mechanism is provision for 'hyper-depreciation' of industry 4.0 investments (Volpe, 2019). Thirdly, a tax deduction related to training in 4IR skills is an option. These three mechanisms have all had positive effects in terms of stimulating investment, capability-building, and economic competitiveness (Volpe, 2019).

However, the question of incentives remains open for debate in South Africa. On one hand, such mechanisms may bolster investment and innovation. On the other hand, incentives are more easily accessed by large firms compared to SMEs, and may not represent optimum value for money for the fiscus. The option of a tax incentive should therefore be on the table, but not form an initial part of the 4IR policy framework.

Digital Innovation Hubs

Digital innovation hubs may serve the following functions: spreading awareness of 4IR technologies, mapping the digital maturity level of firms, training courses on 4IR skills, and the development of industrial R&D projects. These aspects all overlap with the functions of the DST's proposed Converging Technology Platform and 4IR Outreach Centres, which would in essence act as a set of integrated digital innovation hubs.

Incubators and SME Development Programmes

The policy objectives of economic growth, inclusivity, and employment creation all point towards the imperative to support new businesses and SME's, particularly those active in the technological spaces of the 4IR. Such support structures could include incubator programmes that help entrepreneurs and youth to grow emerging businesses towards independence. Incubators could be domain specific (e.g. AI incubator, ecommerce incubator, 3D printing incubator) or converged (e.g. robotic 3D bioprinting). Within the national framework, there is potential for incubators to be linked to the CSIR's proposed Converging Technologies Platform.

One feature of incubators is the potential option for the funder of the incubator to obtain a share of the intellectual property or a shareholding in firms emerging from the incubator. While most publically supported incubators, internationally,

continued

do not utilise this option, it may be investigated as a potential source of sustainable funding for such mechanisms.

8.3. A future of decent work for humans

The future of work is changing, and South Africa needs to respond. Burgeoning research efforts have focussed on the various ways in which technological change is, and will continue be, impacting on skills supply and demand, the contractual structures of employment, and perceptions of work. At the same time, the ILO has formulated a consensus position on the future of work that frames it, in terms of values, as a fundamentally human-centric arena (International Labour Organisation, 2019).

Integrating these imperatives – technological change and humanist values – is a key task for South Africa has it negotiates current and future changes in the world of work.

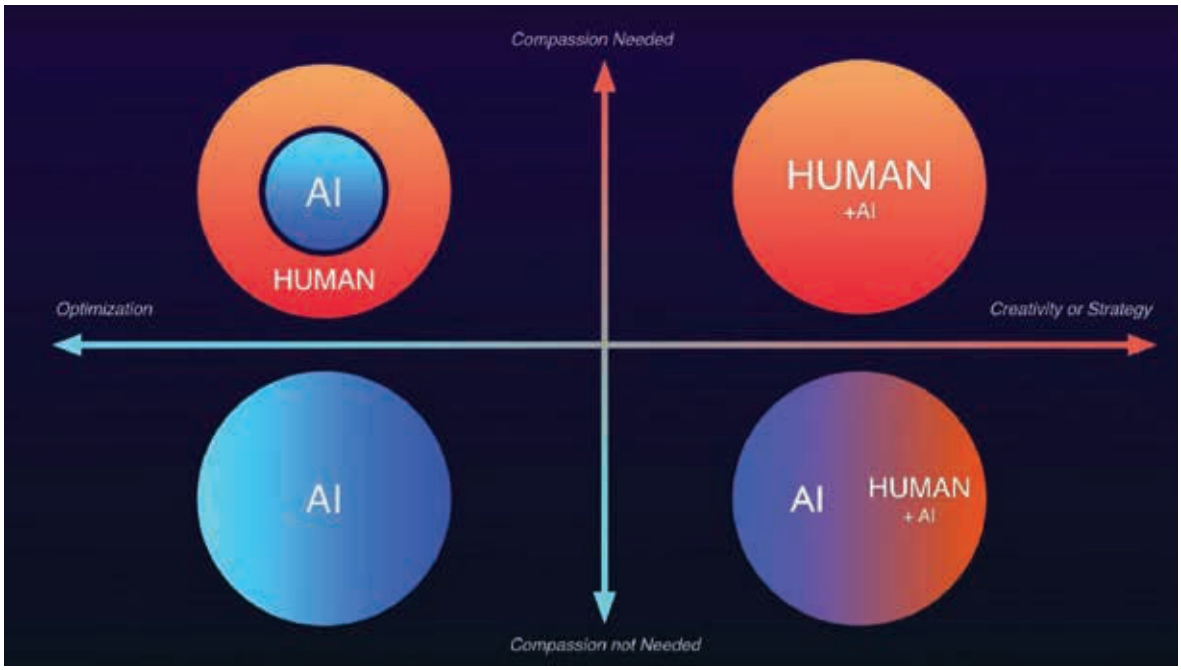
In the policy framework, the area of the future of work needs to be integrated with the area of education and skills development, since both are part of broader systems of innovation and capability-building, and associated labour markets.

One of the central logics of the 4IR is that of ongoing growth in automation. The fundamental change in orientation is that from viewing labour markets as being comprised of humans competing for employment positions, to a view in which humans and machines compete for functional roles. This logic leads to the conclusion that those functional roles where humans maintain advantages over machines are the ones which should be the focus of capability development and other forms of policy support.

> ***"Advocating about general, repetitive and route jobs we need to recreate, add a vertical axis where compassion needed where things are also human centric. You can relook at that and create more work opportunities that fits into these buckets. Where things are repetitive and compassion not needed AI will take that over. With assisted intelligence you will see the warm embrace of humans utilising AI. Moving to the creative side there's plenty of opportunity for humans and human centric and compassionate, move opportunity for human and AI. We need to reshape the world and look at jobs. This will take government as well as stakeholders to shape the better future."***
>
> *Dr Jacques Ludik: CEO, Cortex Logic*

8. Social and Economic Outcomes: Towards a Developmental Agenda

continued



Source: Ludik, 2018

Assessing the potential for automation-induced job losses, and mitigating their impacts, is a critical component of a policy response to the 4IR. This imperative cuts across many policy arenas and government departments, and will have distinct dynamics in different sectors and industries. One general objective is the balance the need for technological upgrading, and therefore economic competitiveness, with the need for decent work and the prevention of unemployment:

> ***"If we are going to displace jobs because of automation and modernization around the mining industry and we displace jobs, what do we do with them? … We have been looking at having various projects in agriculture and having some of the community members getting involved in that. So there are various opportunities. Through processing, beneficiation, to agriculture to actually use the workforce in a different way if we have to automate. We don't take automation lightly. We need to modernize our mine and possibly mechanise…. It's balancing act and we are talking about it, coming up with plans and converting them to implementable actions."***
>
> *Mr Jean-Jacques Verhaeghe: Programme manager for real-time information management systems, Mandela Mining Precinct*

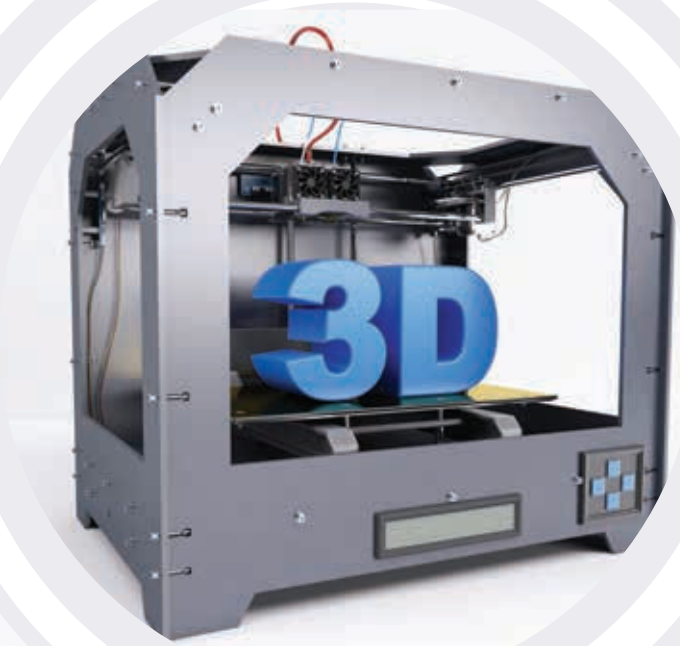
8. Social and Economic Outcomes: Towards a Developmental Agenda

continued

8.4. Transforming human settlements: responsive and competitive cities

> ***"Cities, not nation states, will determine our future survival."***
>
> *Mr Roope Ritvos: Director of New Initiatives at Forum Virium Helsinki*

Internationally, innovation policy at the city level has played a significant role in the public sector's role in innovation systems. Cities are the main economic engines of South Africa. A national policy framework should provide guidelines for unique programmes within South Africa's metropolitan areas. Each city has a unique economic and cultural context, and programmes would need to be devised at the local level to respond to local imperatives. For example, the City of Cape Town is home to an emerging cluster of start-ups in the ICT sector, as well as a space sector that utilises advanced manufacturing. On the other hand, the Nelson Mandela Bay metro area has a major stake in advancing industry 4.0 within its manufacturing-intensive economy. In principle, therefore, a national policy framework could make provision for devolved policy-making, while at the same time establishing a mechanisms for the managers and strategic actors involved at the city level to interact, develop cohesive programmes, and foster mutual learning.



9. Structures for Consultation and Co-ordination

> ***"DTI, DST and higher education [should] get together and make a plan, create a framework, create some glue in the system. We all young in this space we need a concerted effort for that collaboration."***
>
> ***~ Dr Audrey Verhaege***
> Chairperson: Innovation Summit

Any national policy framework on the 4IR would require broad and ongoing engagement. The policy options put forward in this Framework have the potential to inform the debates within such spaces. The Presidential Advisory Commission on the 4IR is positioned to play an effective role as a centralised structure for consultation and co-ordination. Within this ambit, it is important to build a space where the DST, DTI, DHET, DTPS, and other lead departments can co-ordinate their respective policies and strategies, and align these with the national process. The Presidential Advisory Commission will play a leading role in determining how to advance from a general framework to sectoral responses, including the role of stakeholders contributing to specific policies.

Germany's Plattform Industrie 4.0 may provide insights for how to structure and manage a consultation and co-ordination model appropriate to Industry 4.0 and the 4IR:

> ***"Let's benchmark what Germany is doing. They all went through the same learning curve. Platform Industry 4.0 - that government body is working together. The unions are key in this discussion as well. Academics should also sit around the table. Government, Private Sector, Unions and Academics, sitting together around the table, so many topics that need to be addressed… there is no copy and paste, but we need to get a structure."***
>
> *Dr Gunther Kegel, CEO: Pepperl+Fuchs*

A bilateral exchange of stakeholders from Germany and South Africa is a potential learning mechanism. Lessons from the German experience suggests the following requirements for engagement structures:

- A high-level forum for the key government departments to co-ordinate their efforts.
- A meso-level co-ordination forum (for example, at the level of the DDG and their support staff and policy researchers) to co-ordinate strategic and operational aspects of the strategy across silos.
- A forum for all stakeholders to reflect on issues and policy. This includes the active involvement of industry, labour, civil society, and academia.

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SA-EU Strategic Partnership

South Africa has enjoyed a successful, productive and mutually beneficial relationship since the European Commission's Special Programme for Victims of Apartheid was created in 1985, and subsequently with the advent of the first democratically elected Government in 1994. South Africa and the EU signed a Trade, Development and Cooperation Agreement (TDCA) in 1999, which came into force in 2004 and was amended in 2009.

In 2007 SA and the EU established a Strategic Partnership (SP), and following the acceptance of a Joint Action Plan (JAP) in 2007, that facilitates co-operation between South Africa and the EU. South Africa has become one of the European Union's 10 Strategic Partners and the only one in Africa. The JAP promotes a programme of "dialogues" by means of which experience is shared in areas of common interest and strategies are developed to overcome shared challenges across a wide range of fields (social, economic, cultural, etc.).

The Dialogue Facility project is an instrument supporting the Strategic Partnership by giving it a human face through people-to-people dialogues and other related interventions, including communication, visibility and awareness-raising activities.

The Dialogue Facility (DF) has since 2011 to date, facilitated more than 56 dialogues in sectors such as: trade, economics, education, health, science and technology culture, etc.

The Dialogue Facility will provide support such as technical assistance, logistics (conferences, workshops, seminars, and events), support to study tours, research, mentoring, Twinning, etc.

The Dialogue Facility is strategically guided in a partnership between European Union and the government of South Africa. A Programme Management Unit deals with day-to-day administration.

For further information refer to www.dialoguefacility.org

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