Master Class

Priorities Setting with Foresight in South Africa

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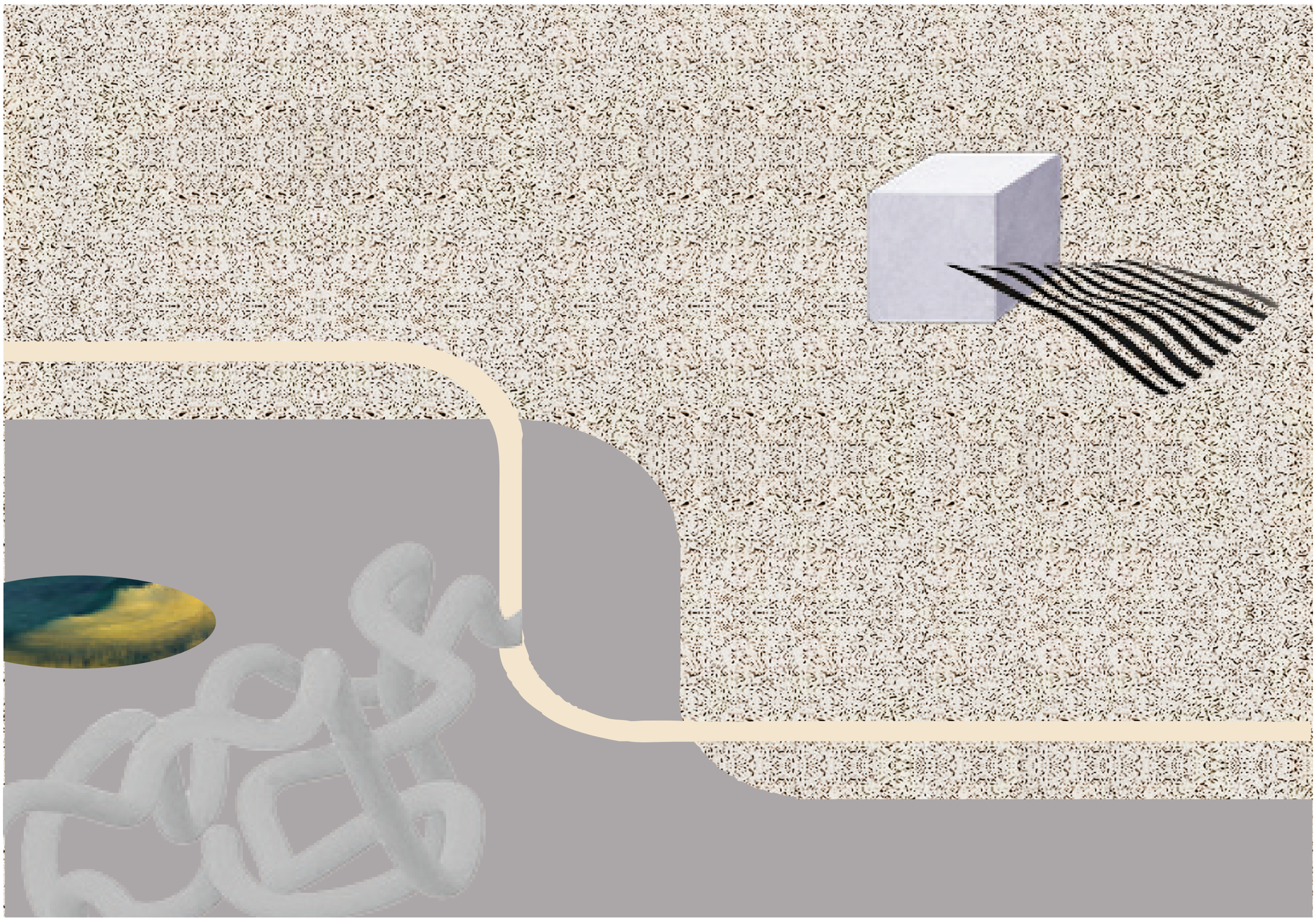

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Abstract

South Africa has only irregularly undertaken exercises to identify priority technology areas, despite government recognition of their importance. Moreover this activity has no institutional frameworks. This article reviews past efforts in this field in South Africa.

In the end of 1990s, the Department of Arts Culture, Science and Technology announced the results of the National Research and Technology Foresight. One of the key implications of these results was that, in contrast to the rest of the world, South African stakeholders fail to recognize the importance of emerging technologies such as nanotechnology, micro-production as well as simulation technologies as cost-effective components of new product and process development. These results appear to have permeated the STI policy and as a result, the country appears to be lagging in terms of research in emerging technologies.

The main focus of the authors is on the findings of the most recent effort supported by the Department of Trade and Industry to identify changes in industrialists' opinions related to technology priorities. The recent results indicate that the country is integrating into the global economy, as national priorities are converging with priorities elsewhere.

Keywords: Foresight; science and technology (S&T) priorities; national innovation system; South Africa
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The broad field of futures research has evolved from the United States since the 1950s and 1960s. There is an extensive list of names used in this field interchangeably when referring to futures research such as long range planning, technology assessment, technology forecasting, technology Foresight and others. The term 'technology Foresight' is used in this study.

Irvine and Martin's seminal work provided one of the first definitions and understandings of Foresight and led to a proliferation of relevant exercises [*Irvine, Martin,* 1984].

Foresight took off in the 1990s as European and then other countries began to concentrate their investments in promising areas of science and technology [*Martin*, 1995]. Several countries including Japan, United Kingdom, France, and Germany have undertaken their own large-scale Foresight exercises. Some of these countries began to establish relevant organizations with a mandate to inform policy. The practice has spread widely and many developing countries have launched their own Foresight exercises.

According to [*Martin,* 2002], technology Foresight is defined as a 'process that systematically attempts to look into the longer-term future of science, technology, the economy, the environment and society with the aim of identifying the emerging generic technologies and the underpinning areas of strategic research likely to yield the greatest economic and social benefits'.

Japan has been one of the leading countries in identifying future technologies since the 1970s. Foresight activities have been institutionalized in the shape of the National Institute of Science and Technology Policy (NISTEP), which is an organization affiliated with MEXT (Ministry of Education, Culture, Sports, Science and Technology) [NISTEP, 2010].

Foresight exercises are widely recognized as an appropriate tool in science, technology and innovation (STI) policy design and decision-making processes [*Havas et al.,* 2010]. The results of the exercises are often used to identify research priorities, orient policies, and to advise on promising areas for policies. According to Meissner and Cervantes, there is a correlation between the use of technology Foresight and a country's innovation performance, indicating that technology Foresight has a positive economic impact on a country's innovative potential in the long-term [*Meissner, Cervantes,* 2008]. Furthermore, Pietrobelli and Puppato argue that the successful development trajectories in both Korea and Brazil were partially due to the efforts to link Foresight exercises with industrial strategies [*Pietrobelli, Puppato*, 2015].

The objective of this article is to review a number of such efforts in South Africa and to report the findings of a recent survey. The recent survey aimed to identify the opinion of relevant stakeholders/industrialists related to the technological needs of the country and to confirm or refute the findings of the dated national Foresight exercise.

The paper outlines the Foresight projects carried out in South Africa over several decades. The latest survey identified the opinions of industrialists and other stakeholders related to the technological priorities of South Africa and updated the findings of the previous national Foresight exercises.

Strategic Priority Areas in Technology Development in South Africa: lessons from the 1990s and 2000s

South Africa has undertaken processes to identify priority areas in technology irregularly. The earliest investigation was undertaken by the Foundation for Research Development (now the National Research Foundation) in the early 1990s [*Blankley, Pouris*, 1993]. The investigation first identified the critical technologies of importance that have been developed in other countries. Next, the respondents — representing large companies with their own research and development (R&D) departments, the then South African Scientific Advisory Council, and others — were asked to rate the various technologies by perceived importance.

Figure 1 shows the results of the ranking. Over 50% of respondents identified environmental technologies as being the most important. Computer Networks and communication systems followed closely behind (49%). In third place were software development (42%) and advanced materials and composites (40%).

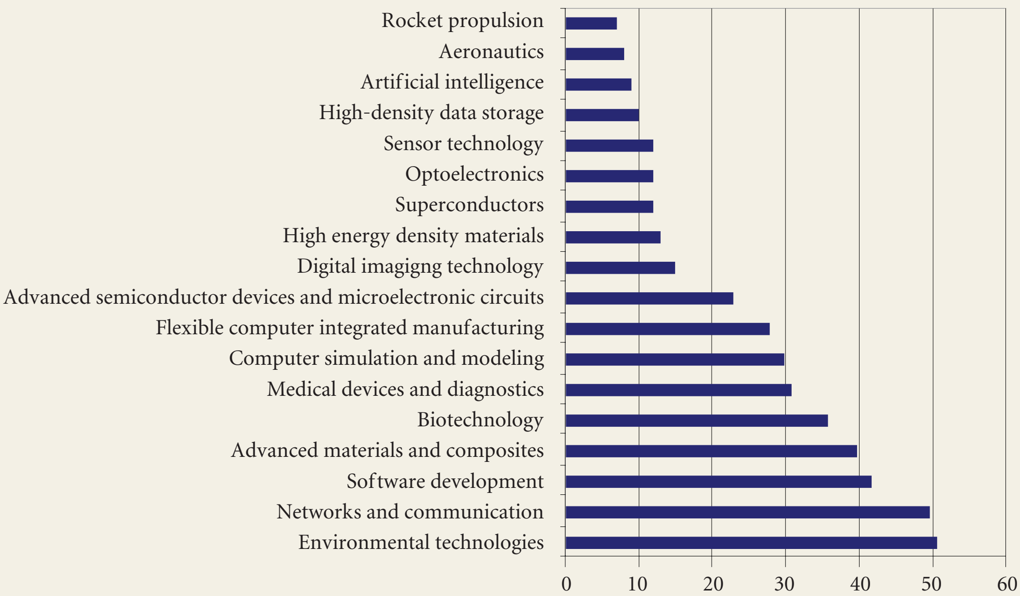
The first official Foresight exercise was undertaken by the Department of Arts, Culture, Science and Technology (DACST). DACST undertook and published the National Research and Technology Foresight (NRTF), which was inaugurated in July 1996 and conducted over a two year period between 1997 and 1999. The results were published in 2001.

The government intended to utilize the results of the Foresight exercise Foresightas inputs in government and private sector R&D investment decision-making, and to strengthen the capacity for research in the higher education sector [DACST, 1996].

The NRTF study focused on the following sectors of science and technology policy:

- Agriculture and Agro-processing;
- Biodiversity;
- Crime Prevention, Criminal Justice and Defence;
- Energy;
- Environment;
- Financial Services;
- Health;
- Information and Communication Technologies;

Fig. 1. **Distribution of Critical Technologies Rated as Extremely Important by Top Decision Makers: Results of a Foresight Exercise in the early 1990s**
(share of respondents who rated each technology as most important, %)



Source: [*Blankley, Pouris*, 1993].

- Manufacturing and Materials;
- Mining and Metallurgy;
- Tourism;
- Youth.

The concept of the survey was based on similar work carried out in other countries. Of the 1500 questionnaires distributed to representatives of the manufacturing sector, 150 were returned. The response rate was hence 10%. The relevant committee accepted this was a good response. To analyse the statements, we developed three indices: wealth creation (WC), quality of life (QL), and a combined index (an average of the first two indices). As a representative example, Table 1 below shows the statements that received the most support from respondents in the manufacturing sector.

The majority of the top-voted statements are policy related. By this we mean that tertiary education institutions, for example, will be transformed to ensure the high quality of appropriate skills, or that industry specific clusters will be created.

The future technologies identified are listed in Tables 2–3 below. The technologies rated as most important were: intelligent communication systems; design and fabrication technology; and concurrent engineering technologies such as CIM, CAD, CAM, etc. The experts considered the least promising technologies to be: biological structures (biotechnology); semiconductor manufacturing technologies; bio-mimetic systems; 'smart' energy buildings; micro- and nano-technologies for fabrication processes; and ceramic materials for high-temperature gas turbines.

It is worth pointing out that respondents did not consider 'futuristic technologies' important. Likewise, the significance of simulation technologies, which are acknowledged worldwide as a cost-effective component of new product and process development, was given limited prominence. The report stated that the typical issues (such as nano-technology and micro fabrication) recommended for future development by Foresight exercises of Pacific Rim countries were only given moderate importance; in some cases, they made up some of the ten least important issues. Moreover, the report highlighted the need for South Africa to improve decision making and the development of niche production.

The next large-scale Foresight project was carried out in South Africa in 2004 by the Department of Trade & Industry (DTI). The resulting report entitled 'Benchmarking of Technology Trends and Technology Developments' study aimed to encompass the following industrial sectors: ICT, tourism, chemicals, biotechnology, automotive industry, aerospace, metals and minerals, culture, clothing & textile and agro-processing. The study endeavoured to identify global technology development trends, specific current and emerging technologies, and the role of such technologies in sectoral development [DTI, 2004].

Within the ICT sector, the most important future technologies were estimated to be wireless network technologies, open source software, telemedicine, and grid computing. In the tourism sector, mobile, environmental, and cultural heritage technologies were considered as highest priority (Table 4).

Strategic Priority Areas in Technology Development in South Africa: up to 2020

The year 2012 marked a new round of updating the country's industrial technology needs with future planning up to the year 2020, a process carried out by the Department of Trade & Industry. A preliminary list of

Table 1. **Evaluation of statements by respondents in the manufacturing sector for the NRTF Foresight Exercise**

No	Topic	Combined Index	WC Index	QL Index	Constraints*
54	Tertiary education institutions (universities and 'technikons') will be transformed to ensure high quality, appropriate skills development that can support a strong manufacturing base	91.94	93.55	90.32	HR, P, F, Soc/Cul
06	Widespread availability of venture capital to enhance the innovation of new products and processes in South Africa	89.29	83.33	82.14	F, P
04	Practical implementation of industry-specific clusters in South Africa to enable the clusters to innovate and compete on world markets	85.63	93.48	77.78	P, HR, F, M
58	Government's appropriate trade and legislative framework will support local industry to meet the challenges of international competition	85.42	87.50	83.33	P
07	Widespread use of intelligent communication systems that will enable SMEs to effectively integrate their skills and knowledge with their chosen industrial partners to form wealth-creating businesses	74.32	78.38	70.27	F, HR, T
60	International transfers and relationship building in the public and private sectors will tangibly help South Africa to use leapfrog technologies to forge ahead	74.32	75.68	72.97	P, HR, F, Soc/Cul
32	Management of new process innovation will be key success factor for most South African companies in the future	74.07	81.48	66.67	HR, T, Infrastr
08	South Africa's manufacturing production will be predominantly characterized by raw material beneficiation through training of downstream processors on value chain management, design and fabrication technology	72.55	78.43	66.67	HR, T, F
03	Practical application of free-trade zones that will facilitate a regulatory framework for importers and exporters to maintain manufacturing standards in the country of product origin leading to the world economy	69.71	81.08	58.33	P
11	South Africa becomes niche-focused in its manufacturing industry and thus becomes a world leader in a limited number of products	67.27	70.91	63.64	T, HR, Infrastr, F
09	Mass customization of products, reduced product life cycle, shorter lead times etc. will become an important driver for South African suppliers to maintain market share on a global basis	65.63	77.08	54.17	T, HR, F
25	Widespread use of practices to eliminate variability in practices and processes is fundamental to competitive manufacturing	61.46	72.92	50.00	HR
61	Widespread use and adherence to international environment and quality standards such as ISO9000, ISO14000 and QS9000, VDA6, SABS series, etc. by South African companies to become competitive and internationally recognised	60.29	62.12	58.46	HR, P, F, Soc/Cul
57	In the future, access to mainstream economic and social activities will discriminate between technologically literate and technologically illiterate individuals and groups	58.47	56.41	60.53	HR, Soc/Cul, P, F
12	South Africa's manufacturers develop small-batch manufacturing capabilities for a competitive edge	58.16	65.31	51.02	T, HR, F, M
31	Development of recycling industry (water, raw materials) that will result in waste-free manufacturing	57.14	42.86	71.43	T, P, F
46	Widespread use of concurrent engineering technologies (CIM, CAD, CAM, etc.) to improve time-to-market by South Africa's manufacturing industries	53.41	68.18	38.64	HR, F, T
29	Widespread use of industrial design skills where designer materials will be a fundamental part of new products in the future	53.13	62.50	43.75	HR, T, F

* HR – human resources; P – political; F – financial; T – technological; M – market; Soc/Cul – socio-cultural; Infr – infrastructure.

Source: compiled by the authors.

Table . 2. **List of future technologies from the 1999 Foresight exercise: short-term horizon**

Group of technologies	Components
Continued process and product development of basic materials	• Alloy development; • Polymer development, especially through indigenous coal-based technologies; • Indigenous biomaterials, e.g. natural fibres; • Further processing of precious metals e.g. Platinum group
Downstream product technologies for metal products (e.g. stainless steel, aluminium, precious metals)	• Near-shape processing technologies; • Deeper knowledge and research in optimized technologies for metal forming and joining; • Design and integration of materials in optimum products
Downstream product technologies for polymer products	• Advanced moulding technologies; • Computer-based analysis to support product and process design; • Life-cycle management; • Simulation, modelling and visualization
Computer-based support technologies	• Product design optimization (including virtual prototyping); • Process design and optimization (including plant operation and layout); • Tooling design
Design/product data interchange in value chains	• Development of more energy-conserving processes for raw materials treatment and usage

Source: compiled by the authors.

technologies that are significant for certain sectors up to the year 2020 was developed based on the experiences of the United Kingdom [Government Office for Science, 2010].

Methodology for selecting technology priorities

We developed an open-ended questionnaire related to technology trends and distributed it to several stakeholders, including representatives of key sectors under the remit of the Department of Trade & Industry. The questionnaire was also sent out to researchers possessing close ties with industrial associations, the Technology and Human Resources for Industry Programme (THRIP), and the Council for Scientific and Industrial Research in South Africa (CSIR), and other organizations.

The response rate was 22%. Compared to similar exercises, this response rate is satisfactory. The first national Foresight exercise in South Africa got a response rate of just 10%. Most responses came from experts in the chemicals and pharmaceuticals industries (10), followed by the automobile sector (8), textiles, clothing and footwear industry (7), energy (6), and heavy industry (6). An analysis of sectors' current characteristics allows

Table 3. **List of future technologies from the 1999 Foresight exercise: long-term horizon**

Group of technologies	Components
Development of capabilities to implement 'miniaturization' and 'smartness' into products	• Increase precision manufacturing and near-shape technologies; • Direct manufacturing technology ('free-form manufacturing without tooling'); • Integrated sensor/actuator technologies into products
Development of customized materials designed for specific product needs	• Improved methodologies for materials design and development; • Designing with environmentally-friendly/recyclable materials
Development of a manufacturing industry aimed at niche 'information-age' products based on local strengths, despite having essentially missed out on the opportunities of the semiconductor/active materials era in the 1970–1990s	
Introduction of biotechnology development methods to natural fibre optimization for structural composite applications	

Source: compiled by the authors.

Table 4. **Priority technologies identified in the 2004 Foresight exercise by the DTI**

Sector	Technology
ICT	• Wireless Network Technologies • Home Language Technologies • Open Source Software • Telemedicine • Geomatics • Manufacturing Technologies • Grid Computing • Radio Frequency identification (RFID)
Tourism	• Mobile Technologies • Wireless Technologies • Internet • Human Languages • Environmental Technologies • Cultural Heritage Technologies
Chemicals	• Extraction of minerals from coal ash and low value slag • Fluorine generation and fluorinated organic chemical intermediates, • New performance chemicals improving the recovery of minerals in the mining sector such as polymer used in solvent extraction processes • Technologies decreasing economies of scale for chemical plants and hence enabling smaller production facilities to compete against the mega plants • Low-cost diagnostics and aroma chemicals production • Development of biodegradable and high-performance polymers • Bio-diesel and products from alpha-olefins • Generic pharmaceuticals for meeting future demand for antibiotics and/or anti-retroviral
Biotechnologies	• Recombinant therapeutic products and production of generic medicines • Vaccines against important infectious diseases such as HIV/AIDS, TB, malaria, rotavirus and diarrhoea • Diagnostics methods used for screening, diagnosis and monitoring or prognosis of diseases by laboratory methodologies • Commodity Chemicals from Biomass • Energy from Renewable Resources like plant biomass • Biocatalysts
Automotive Industry	• Development of lightweight materials • Development of alternate fuels e.g. fuel cell technology • Sensors, electronics and telematics • Improved design and manufacturing processes
Aerospace	• Development of composite materials • Development of hyper aero-thermodynamics • Development of sensor usage • Health and usage monitoring systems • Noise abatement • Improved manufacturing processes
Metal & Minerals Sector	• Light materials extraction • Alloy technologies, especially in magnesium • Process improvement
Cultural Sector	• Product Technologies • Internet • Online Marketing • Mobile Technologies • Wireless Technologies • Advanced Materials • Human Language Technologies • E-Commerce • Environmental Technologies • Portals

Table 4 (continued)

Sector	Technology
Clothing & Textile	• Intelligent Textiles • High-performance and technical textiles • Value-Added Natural Fibres - testing systems for foreign fibres in Mohair and wool; yarn formation; dying and finishing technologies • ICT for product and process improvement
Agro Processing	• Real-time detection of micro organisms in food • Sensors for online, real-time control and monitoring of food processing • DNA / RNA chip technologies to speed detection and analysis of toxins in foods • Food pathogen sensors • Separation modules that force molecules into confined environments • Real-time detection systems for verification and validation of intervention technologies used in Hazard Analysis and Critical Control Points (HACCP) systems • Better understanding of tolerable intake levels for nutraceuticals/dietary supplement components • Techniques to inactivate micro organisms to yield safer foods with extended shelf lives • Standardized edible food packaging films • Biological (e.g. bacteriocins) and chemical inhibitors to prevent or slow growth of pathogens in food • Technologies for food traceability

Source: [DTI, 2004].

us to draw the following picture. The majority of respondents were in the manufacturing industry, while a smaller proportion was in distribution and assembly. The average age of respondents' companies was 33 years old. Companies employed 900 people on average. Almost two thirds (63%) of companies declared that they exported their products in sectors such as metallurgical and chemical products, textiles, electronic components and equipment, etc. Approximately a quarter of respondents claimed to be importers, primarily in semi-processed chemical materials, metallurgical rolled stock, power facility and electronic components, medical and pharmaceutical products, etc. Most imported products come from the US and Europe, although a significant share of imports is from Japan, China, and India.

Respondents identified the US, and countries of Europe, Asia, and Africa as potential markets. Respondents said that their companies' turnovers ranged from one million to more than two billion South African Rand (approximately USD 77,416 to USD 155 million).

Main results

From the 20 technologies in the list, advanced manufacturing technologies were most often identified as key technologies (58% of expert respondents). The second most frequently cited key technologies were those connected to modelling and simulation for improving products and processes, reducing the design-to-manufacturing cycle time, and reducing product implementation costs (34% of respondents). Intelligent sensor network and global computing technologies came in third place (16%).

The technologies in various sectors that respondents identified as being of most importance at both the current time and in the next 5–10 years are shown in Table 5 below.

Table 6 shows the barriers to technological innovation as identified by respondents. The most frequently cited barriers were the high costs for innovation, inadequate funding, and lack of necessary resources. It is note-

Table 5. **Technologies perceived by respondents as important today and in the next 5-10 years, by sector**

Sector	Most important technologies	
	Today*	In the next 5–10 years
Aerospace and defense	• Industrial robotics (we are consumers and purchase products from overseas suppliers) • Micro-manufacturing (infancy) • Precision mechanical manufacturing (very important) • Data fusion software (in process) • Infrared optical systems (in process) • Electro-chemical processes • High-speed machining • Additive manufacturing technologies • Space grade sub-systems (in process) • Radar, radio frequency, microwave, electro optics	• Infrared imaging technology manufacturing • Laser communication systems • Embedded software for space systems for radiation tolerant systems • Improved industrial robotics • More energy and eco-friendly systems • Radar, radio frequency, microwave, electro optics
Electronics and ICT	• Biometrics (limited) • RFID (limited) • PDA's (available but without local support) • Geographic register for South Africa • Secure and reliable communications • Precision mechanical manufacturing (very important) • Space grade sub-systems (in process) • Linux software development (mid to high importance for free software)	• Biometrics • Infrared imaging technology manufacturing • Laser communication systems • Geographic register for South Africa • Secure and reliable communications • Embedded software for space systems for radiation tolerant systems • Space grade sub-systems
Clothing, textiles, leather and footwear	• Energy efficient processing machinery • Industrial robotics (imported) • Colour physics • Micro-manufacturing (infancy) • Micro-processor controlled machinery with interactive capability	• Flock printing • Coating • Anti-microbe technology • Alternate means of treatment and disposal of factory process effluent • Micro fluidic sensors and diagnostics, lab on a chip • Improved industrial robotics • More energy and eco-friendly systems • Renewable energy
Automobile	• Biotechnology-specific application that are industrially relevant • Stainless steel manipulation • Automation of the manufacturing process • High speed machining • Hybrid Injection moulding machine (advanced) • Robot Welding (available) • Vacuum Forming (available) • Electro-chemical processes • Powder technology/sintering • Automobile raw material supply chain and value add (not nearly sufficiently available) • Automobile tier 1&2 manufacturing supply upgrade technologies (not nearly sufficiently available) • International partnerships for technology (not sufficiently available) • GRP manufacturing processes (not fully available in South Africa) • Film for covering glass for security and heat load (not available in South Africa) • Better utilization of available energy resources, including solar energy and fuel cell technology	• Develop further use of polyurethanes • Metal pressing • Manufacturing expertise for renewable energy • Automobile tier 1 & 2 manufacturing facilities • World class infrastructure manufacturing support • High temperature sintering • 5-axis high speed machining (HSM) • Additive manufacturing technologies • Material technology change • Manufacture of plastic canopies • Polyurethane technology

Table 5 (continued)

Agro-processing	• Electronic human interaction platforms (technology available only in imported third and fourth tier end user devices and applications. No visible first or second tier end user support for ICT in the sector) • Modern can & closure manufacturing (status evolving) • Modern metal deck printing technologies • Barrier technologies for safer food storage (not available in South Africa) • Food biotechnology	• Oil stabilisation • Catalysis to upgrade fuel • Water gas shift • Hydrogenation of pyrolysis oils • Modern can and closure manufacturing equipment • Tool & die design and manufacturing • Modern metal deck printing technologies • Emulsifiers • Gasification
Chemicals and Pharmaceuticals	• Barrier technologies for safer food storage (not available in South Africa) • Biopolymers, antibacterial polymers (not available in South Africa) • Sensing and smart polymers (not available in South Africa) • Advanced process control systems (chemical transformation unit operations) • Powder technology/sintering • Sterile manufacturing • Biotechnology (industrially relevant applications)	• Biotechnology (industrially relevant applications) • Pyrolysis, oil stabilization, catalysis to upgrade fuel, gasification, water gas shift • Hydrogenation of pyrolysis oils • Micro fluidic sensors and diagnostics, lab on a chip • Polymers based on bio-sources • Sensing and smart polymers • Automated sterile manufacturing
Creative Industries (Craft, film, television, music, games etc.)	• IT Security • Digital animation • Secure Communications • Secure Printing (personalized and tamper-proof documents)	• Secure fast internet lines • Visualization of complex data • Secure printing (personalized and tamper-proof documents) • Secure communications • Co-creation tools
Energy	• Renewable solutions, design and manufacture • Small wind turbine design and manufacture • LED lighting technologies • Induction cooking for mainly residential market • Heat pumps for water heating high in both residential, commercial and industrial markets • Renewable technologies for mainly residential market	• Small wind technology • LED lighting technologies • Hot water systems • Renewable sources • Improved industrial robotics • Plasma technology, nuclear technology, nanotechnology, mineral beneficiation • Small wind technology • Manufacturing expertise for renewable energy • Better utilization of available energy resources, including solar energy and fuel cell technology
Metallurgy, Capital and Transport Equipment	• Router moulding, plastic injection moulding • Complex brackets using different materials • Robot welding • Casting, forgings manufacturing • On-board computer electronics • Display modules • International partnerships for technology (not sufficiently available) • Automobile tier 1 & 2 manufacturing supply upgrade technologies (not nearly sufficiently available) • Automobile raw material supply chain and value added (not nearly sufficiently available) • Casting • Wear casting (available) • Electro-chemical processes • High speed machining • Additive manufacturing technologies • Industrial robotics (we are consumers and purchase products from overseas suppliers) • Micro-manufacturing (infancy)	• Router moulding, plastic injection moulding • Complex brackets using different materials • Robot welding, casting, forgings manufacturing, on-board computer electronics, display modules • World class infrastructure manufacturing support • Automobile tier 1 & 2 manufacturing facilities • Improved industrial robotics • Plasma technology, nuclear technology applications, nano-technology, mineral beneficiation • More energy and eco-friendly systems

* The status of technologies stated in brackets is as described by respondents.

Source: compiled by the authors.

Table 6. **Barriers to technological Innovation** (share of respondents who chose each option, %)

Barriers to technological innovation	Degree of influence		
	Low	Average	High
Innovation costs too high		10	18
Inadequate funding		11	20
Lack of necessary resources		12	18
Excessive perceived economic risk	4	11	15
Licensing constraints	19	7	2
Lack of qualified personnel	3	15	12
Lack of customer demand for new goods and services	8	14	8
Insufficient flexibility of standards regulation	11	9	10
Organizational inertia within company	8	12	6
Lack of marketing information	12	10	5
Lack of technology information	13	8	6
Lack of cooperation with other firms	12	12	5
Other (specify)			2

Source: calculated by the authors.

worthy that more than 50% of respondents identified a lack of financial resources as a critical barrier.

56% of responses stated that they acquire technology through their own R&D (Table 7). The next most commonly used approaches are by having formal agreements with local companies (13%) and with foreign companies (12%). Only 18% of the companies mentioned acquire technology through imitation. It should be emphasized that a number of companies mentioned that their research was done abroad.

Table 8 shows the policy measures identified by stakeholders as useful for their sectors. The most frequently cited measures were fiscal incentives (23%), innovation programmes (21%), and technology platforms (20%).

Participants of the survey offered several suggestions to promote and support local production, including:

- Provide more training on local product development skills;
- Boost exports;
- Improve skills in fundraising to attract investment;
- Make raw materials available at globally competitive prices;
- Provide financial and time resources for concept testing;
- Liberalize labour laws;
- Modernize transport and logistical infrastructure;

Table 7. **Acquisition of Technologies** (share of respondents who chose each option, %)

Undertake own research and development	22
Through formal agreements with companies abroad (e.g. licensing)	12
Through formal agreements with local companies	13
From universities and research councils	10
Through embodied technology in equipment and machinery	9
Through imitation	7

Source: calculated by the authors.

Table 8. **Useful policy measures (share of respondents who chose each option, %)**

Question: Which policies could help your organization's activity?

Cluster Initiatives	11
Technology Platforms	20
Innovation Programmes	21
Regulation	10
Competition Regulation	5
Quality Regulation (Labelling, Procurement)	8
Fiscal Incentives	23

Source: calculated by the authors.

- Reduce duty exemptions for Southern African Development Community (SADC) countries.

Almost half of respondents (47%) said they participate in government technology support programmes. Suggested ways to improve such programmes included:

- Increase funding for R&D;
- Provide funding for purchase of capital equipment;
- Increase the salaries for postgraduate students;
- Improve the quality of skills and educational programmes;
- Respond more quickly to enquiries from business;
- Reduce bureaucracy;
- Provide R&D commercialization opportunities for local developers and inventors.

Conclusions

Over the last three decades, the concept of Foresight has become one of the most important tools for priority-setting in science and innovation policy. Typical rationales for Foresight exercises have included exploring future opportunities and reorienting science and innovation systems in parallel with building new networks and bringing new actors into the strategic debate [*Georghiou, Keenan*, 2006]. It should be emphasized that Foresight exercises are pursued at different levels, ranging from the organizational to the supranational.

Developing countries or countries with small innovation systems have the potential to benefit from Foresight exercises as well as more developed countries. Selectivity is important for these countries, however, as the costs of offering uniform horizontal support to all industrial sectors would be too high and probably not feasible [*Lall*, 2004]. Similarly, technologies are not freely available and can only be absorbed if the country is willing to assume the associated costs and risks. Foresight exercises can undoubtedly provide valuable guidance on the above issues.

In South Africa, in contrast to the rest of the world where prioritization exercises are institutionalized and regular, prioritization efforts are undertaken intermittently and are usually the result of efforts by individual government departments and/or government agencies. This lack of prioritization and coordination of research and innovation agendas has exaggerated the imbalances within the country's system of innovation. Furthermore, industrial enterprises are forced to set up their own technology monitoring mechanisms which leads to substantial diseconomies of scale within the system.

It is interesting to discuss the findings of the most recent survey (2012) in light of the results from the 1999 Foresight exercise and international experiences. An important finding of the 1999 Foresight exercise was that the participants/stakeholders did not see 'futuristic technologies' as important. The most frequently mentioned technologies recommended for future development in Foresight processes in the world's leading countries were only given moderate importance in South Africa in 1999 (and in some cases were among the ten least mentioned technologies, e.g. nano-technology and micro-production). Similarly, the power of simulation technologies, which are acknowledged worldwide as cost-effective components of new product and process development, was given limited prominence. It should be mentioned that the results of the 1999 Foresight appear to have permeated the scientific and technological system and as a result, the country appears to be lagging in terms of research in emerging technologies [*Pouris*, 2012].

In contrast, the 2012 survey found that stakeholders recognized the importance of emerging and enabling technologies. ICT related technologies (such as secure internet communications, biometrics, robotics, sensors, etc.), biotechnology, and clean energy technologies) were identified by stakeholders as of current importance. Similarly, stakeholders identified 'advanced manufacturing technologies', 'modelling and simulation for improving products, perfecting processes, reducing design-to-manufacturing cycle time and reducing product implementation costs', and 'intelligent sensor network and global computing' as of critical importance for their companies' operations. It should be mentioned that these technologies are at the forefront of priorities internationally. Advanced manufacturing technologies and on-demand manufacturing now attract the attention of most governments around the world in the same way as nanotechnology attracted international support in the early 2000s. The US government is the world leader in terms of allocating substantial resources for advanced manufacturing technologies [*Hewitt*, 2012].

It is clear that the priorities identified during the 1999 Foresight exercise are not necessarily the current STI priorities. In this context, it is important to mention that — in contrast with other countries which monitor and disseminate information related to new technologies — South Africa has no such mechanism. Most countries have institutionalized the monitoring of international priorities and the development of local priorities, and Japan's Foresight exercises are perhaps the most well-known. As discussed here, the lack of South African efforts in the field may be detrimental to the country's manufacturing sector and the performance of its national system of innovation. South Africa has a relatively small national system of innovation with only 0.76% of gross domestic product spent on R&D [HSRC, 2014]. Furthermore, the Department of Science and Technology [DST, 2015] now seeks to encourage the business sector to spend more on R&D to increase the country's overall R&D expenditures. Foresight exercises, among others, may provide the guidance needed by the business sector to fulfil this task.

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