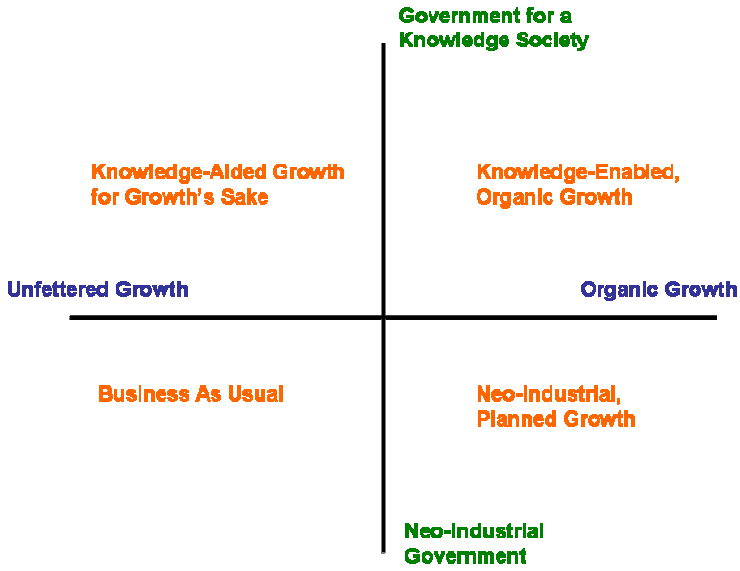
Three Biotechnology-Related Scenarios for Gauteng

24 April 2009

Introduction

From October 2008 to March 2009 the Cooperation Framework on Innovation Systems between Finland and South Africa (COFISA) undertook a Foresight exercise focusing on the biotechnology sector in Gauteng[1].

Two workshops were held as part of this exercise. During the first workshop three proto-scenarios[2] were presented for Gauteng, each associated with one of the top-most or right-most quadrants of the diagram to the right. (There was no scenario associated with the bottom-left quadrant "Business as Usual").



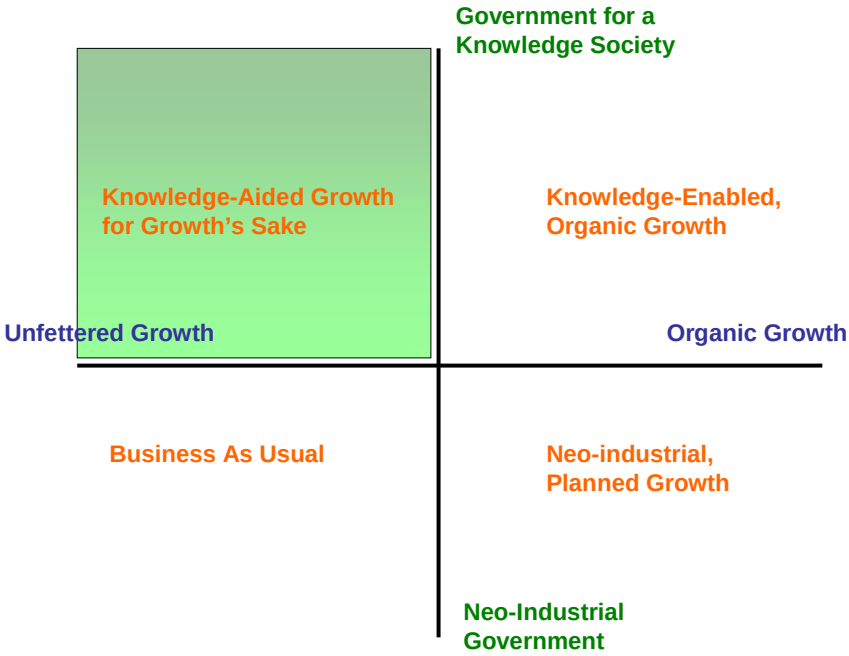
The workshop participants then formed three groups which engaged in a process that resulted in biotechnology-related scenario fragments being written, by the participants themselves, that were relevant to their proto-scenario.

These scenario fragments, together with further inputs solicited by email after the first workshop, were then edited and integrated into their associated proto-scenario, resulting in three biotechnology-related scenarios for Gauteng, as set out below. For easy reference, the biotechnology-related material is presented with a grey background.

[1] For more information concerning COFISA and the Foresight exercise, see www.cofisa.org.za.

[2] The three proto-scenarios had been derived from COFISA's earlier provincial Foresight exercise.

Scenario 1: Biotechnology in the Context of Knowledge-Aided Growth for Growth's Sake



The years: 2009 to 2019

The Gauteng Provincial Government (GPG) was very growth oriented. Their vision was to push for ever-increasing economic growth, as this growth (it was believed) served to undergird the growth of the whole country. It was also very good for Gauteng! While the poorer sections of Gauteng's society were not forgotten, it was believed that they would benefit indirectly: all segments of the population, including those on the periphery, would benefit in the wake of surging growth.

In 2009 the (new) national Government took the strategic decision that the key to a better future for all South Africans was the establishment and development of a knowledge society, at all levels, in the country. This strategy was then implemented by an initial focus on Gauteng (being by far the most economically advanced province), and the Eastern Cape (which was severely under-developed).

The GPG embraced this strategy, both for the way Government operated and delivered services, and for the province as a whole. They recognised that promoting the knowledge society was essential to achieving the high growth rates that they had targeted, and so they set about implementing the strategy with great energy. However, the level of understanding on the part of the GPG of the implications of moving towards a knowledge society left something to be desired, although this was not readily evident at the time. Everyone's enthusiasm led to hasty decisions and an obfuscation of the fundamental issues.

The GPG set up a forum with the private sector, although this meant in practice large companies, not SMMEs who did not have resources to devote to forums. The purpose of the forum was to achieve a consensus between the public and private sectors as to the best way to pursue the goal of a knowledge society. A sophisticated strategy was developed and agreed to, which emphasised the role of technology. This consensus unlocked a large amount of energy and enthusiasm for making the desired future happen.

So, for example, the GPG set about (as it thought) reforming its processes to bring them into line with the requirements of a knowledge society. It did so by entering into a few strategic partnerships with IT companies who impressed the Government with a range of the latest IT solutions. They were offered some superb deals in which the cost of software licences were heavily discounted for two years, on condition that a full solution was deployed, including server-side applications. These solutions were implemented with great speed and commitment from the top, but staff at an operational level experienced the exercise as a huge frustration and inconvenience. Some attempt was made to re-engineer processes followed by the several Government departments, but this was most often related to the need to change processes to fit the limitations of the IT solutions.

It was not only the ICT sector that was seen by the GPG to be a key to the growth that it sought. High-tech companies in a range of sectors were wooed to the province in the belief that their presence would boost the economy, and also that they were most compatible with the desired knowledge society. Biotechnology companies were given

special preference and several multinationals in this sector established manufacturing operations in Gauteng.

In the drive to establish a biotechnology industry there was a focus on licensing in new biotechnologies for the manufacture of biotechnology products that were customised for the South African market. In addition, technology was licensed that could be used by the South African biotechnology industry to target the international market. Technologies were adapted to suit local raw materials and were made more robust for local conditions (such as non-standard raw materials, erratic water and power supplies, poorly educated workforce).

Gauteng became an early adopter of biotechnologies which fitted well with the emphasis on modifying and improving technologies for local conditions. The province offered an ideal environment to pilot technology development and adaptation, with its combination of rich and poor. As a technology conduit, it could modify the technology for application in the rest of Africa.

An example of a biotechnology-based service that was modified and improved in Gauteng was rapid testing. The speed and quality of tests were dramatically improved. Tests were performed at the nanometre level. This reduced the per-test cost as well as making the test available at the point of examination of the patient, thus obviating the need to send samples away for analysis at a central laboratory.

The revenue produced from the rapid growth of biotechnology through in-licensed technologies generated the resources and an enabling environment to catalyse an open innovation process. R&D started to take off in Gauteng, with the multinationals as final clients of products. Personalised franchise medicine clinics with tailored technology applications sprang up in all of the more affluent areas.

In short, the biotechnology industry added to the economic growth and to new job opportunities in the country, and Gauteng became an entry-point for technology and technology-based products to Africa.

The universities responded to the changes in the biotechnology sector by becoming more relevant and applied in their R&D focus so that they could service the needs of the multinationals and other companies who were importing technology. Universities focused on applied research and consulting to large industry, both nationally and internationally. This led to training being more applied in order to serve these expanded markets; training thus became more market driven.

Some of the large multinational companies involved in biological manufacturing became prominent in Gauteng. High-end consumer demand grew, both in Gauteng and nationally, stimulated by the availability of new products. This led to a growth in demand for qualified biotechnologists.

With the success of the multinationals, a biotechnology cluster emerged to support the burgeoning biotechnology manufacturing industry. A range of services was provided, particularly those that the multinationals could outsource easily. These included bio-analytical services and support, the production of essential materials such as key process enzymes and microorganisms. gene banking services, and bioinformatics services and support. This led to the re-emergence of funders for the industry due to the growth in the application of science-based research to the needs of the growing market. Relations between government and industry, that had previously suffered marked deteriorated, began to improve.

One innovation introduced by the GPG towards stimulating technology companies was to give preference in their procurement processes to companies that had implemented specified technology solutions for enhancing their own business processes. This encouraged the growth of technology-intensive business services (TIBS), which reinforced the technology-led attempt at creating a knowledge society, but did not especially favour knowledge-intensive business services (KIBS) as the latter were not focused on particular technology systems.

Nevertheless, results from the GPG's policies and initiatives were initially impressive, particularly in respect of Gauteng's first-world economy, and the poorer sectors benefitted from the growth through the creation of jobs. However, the major flows of money were within the top layers of the economy, and there was very little direct stimulation of the informal sector.

Medical genetic tourism became a significant industry in South Africa, based in Gauteng. Some biotechnology entrepreneurs licensed in the newest embryonic screening and selection technologies – some of which are illegal in most of the developed world – and began offering designer and diagnostic services to those willing to pay. Society adapted to embrace the new technology in an ethical manner, and the South African bio-ethicist community realised that they had to also change their old-school views and participate to generate a new regulatory environment.

In addition, companies began offering genetically personalized preventative and therapeutic services (including anti-aging) linked to packaged holidays.

Several of South Africa's leading knowledge specialists, while admiring the spirit of the GPG's vision of a knowledge society, raised grave concerns about the way it was being implemented. They pointed out that the approach being taken was superficial and was missing the mark. They found an unexpected ally in Gauteng's financial services sector who, being well-integrated with the global system in which the role of knowledge was increasingly well understood, were more aware than most that the attempts in the province were fundamentally flawed. In fact, they had come to the realisation that their own models were based on industrial-paradigm assumptions, and were therefore out of date. But in the face of the successful growth being achieved, the voices of the critics were played down.

The growth resulted in a steady stream of immigrants to Gauteng, from other parts of South Africa and the rest of the world. Consequently, Gauteng's infrastructure began to take strain under a load that it was never designed to carry. The most concerning factor

in this regard was Gauteng's ballooning use of water, of which there was a limited supply. The GPG tackled this problem with energy and vision, and successfully implemented measures that both reduced water consumption and water wastage. A water crisis was avoided, at least for the moment.

In 2016 Gauteng suffered a financial crisis. Many South African banks had strong ties to banks overseas, and this was certainly true for ABSA in which Barclays had a strong interest. Through a series of ill-considered actions and unforeseen circumstances (which brought memories of the financial crash of 2008) Barclays ended up in a precarious position and had to be propped up by the British government. This sent shockwaves through South Africa's banking industry in general, and through ABSA in particular. What aggravated the situation was that certain sections of ABSA had been operating outside of company guidelines, and the result was that they overextended the bank by lending money to people who were unable to afford the loans. ABSA was liable, and this combination of circumstances resulted in a run on ABSA's money. Depositors withdrew their savings in droves, and ABSA started to topple. Other banks were also in danger of folding. ABSA was rescued by a buy-out by a Dubai-based bank, who in short order moved top management control of what had been ABSA to Dubai. In addition, they moved ABSA's listing to the Dubai International Financial Exchange (DIFX).

At the urgent insistence of the GPG, the national Government responded by shoring up some of the other banks who were in danger of going under, in effect partially nationalising them. This move brought welcomed stability to the sector, although there were dire warnings of its long-term consequences.

Despite the intervention, ABSA's move from the JSE had a knock-on effect a few months later when several other financial services companies, attracted by the benefits that erstwhile ABSA was enjoying, also moved to the DIFX. A trickle turned into a steady flow, and by the end of 2018 the number of companies listed on the JSE had dropped by 6% (the figure was 22% for the financial services sector), and more than half of the companies that moved had above-median turnover (as determined in 2016).

Towards the end of the decade there were more and more complaints coming from spokespersons of the informal sector and the poorer areas of the province that the growth was in fact not benefitting them as had been the assumption. Yes, Gauteng's per capita output had grown in leaps and bounds for six of the previous nine years (the last three years had been flat due to the financial crisis), but even in the years of high growth the hard reality was that the gap between rich and poor had widened, there was even some evidence that poverty was worsening in some areas, and these trends showed no signs of abating.

The years: 2021 to 2030

As the teens rolled into the twenties it became clear to everyone involved that the technology-led 'knowledge society' of the GPG had not delivered anywhere near what the expectations had been. There were some bright spots, such as the learner registration system for entrants into Grade 1, but none of the transformations in service delivery in the areas of education and health, to name but two, had been realised.

The lack of progress placed the relationship between the public and private sectors under strain. The GPG began asking hard questions as to why the benefits of the IT systems were not being experienced, particularly by those on the periphery. After a considerable muddle and confusion, the IT companies began speaking with a coherent and consistent message: what was missing (they said) was IT infrastructure deployed within the poorer communities. This would enable them to link in to the systems already deployed. It was more of the old technology-led approach and was roundly criticised by the academic community, and knowledge experts in particular.

This time many in the GPG listened to the criticism and did not simply accept the arguments for buying more technology, but their analysis continued to be superficial. For most their new perspective was as simplistic as their initial adoption of the knowledge society strategy: instead of seeing that technology-led transformation was fatally flawed, many in the GPG came to the conclusion that it was the concept of a knowledge society *per se* that was a pipedream. There was therefore a swing away from the knowledge

society strategy on the whole, and in particular, a backlash against ICTs and against the notion that science and technology had an important role to play in poverty reduction.

Others in the Government tried to point out that a knowledge society strategy had in fact never been attempted, that the goal of a knowledge society was still valid but that the means of getting there had to be changed. Yet others began pushing for a more centralised and planned approach to achieving the social goals that all were agreed upon. The issue became hugely politicised and polarised, and given Gauteng's place in South Africa's economy, the whole country felt the impact in some or other way.

One specific consequence of the growing disillusionment was that a commission was set up to investigate whether the IT companies had fulfilled their obligations when they implemented the Knowledge Society projects. The conclusion was that they had failed to deliver properly, and the GPG then took the far-reaching decision to withhold payment on the ongoing contracts. This action provoked the anticipated response, namely litigation by the IT companies, which is not yet resolved.

The financial services sector, having shrunk due to the crisis, continued to run counter to the general trend. Perhaps in response to the crisis they realised that innovative thinking was essential to their survival. Having realised that their financial and business models needed reworking to reflect the assumptions and dynamics that were appropriate for a knowledge society, and that by doing so they would be well-positioned to address what was an emerging opportunity, many of the leading companies in this sector undertook programmes to revise their models. They were entering new territory, and although many of them made use of international expertise, the task of adapting to local conditions was anything but straightforward.

In the aftermath of the financial crisis, with poverty being an ever-present issue, general disillusionment with government and the crumbling medical infrastructure, more and more of Gauteng's populace began turning to traditional healers and medicine. Because of the shortage of indigenous plants in the wild, an increasing number of products based

on indigenous knowledge (IK) started being produced using biotechnology methods.

IK-based traditional medicines were produced through a variety of technologies including (a) plant tissue culture techniques, (b) growth of plant cells in liquid fermentation, (c) production in microorganisms or plants following cloning of the genes involved in the biosynthetic pathway, to produce the compound of interest, and (d) production using biocatalysis with tailored enzymes.

A particular challenge was to prevent higher death rates from HIV and TB. Concerning the use for IK for these purpose it was essential to sift out bogus approaches being promoted from genuine practitioners with sound therapies. Traditional practices that were useful and/or benign needed to be identified and amplified. Two steps were taken to achieve this:

- A country-wide survey was undertaken that helped identify the useful and benign practises of the traditional healers. This study was done independently and was sufficiently robust to answer conclusively the question of efficacy. Those practises that were identified as useful were then put through a rigorous process of clinical trails. Those that survived this screening, and were statistically and biologically significant, were used in downstream applications.
- Clinical trials were conducted of those remedies that were already in widespread use to weed out unsound methods. Genuine practitioners and their remedies survived the close scrutiny of these scientifically-structured clinical trials.

In the years leading up to 2030, the national efforts to harvest maximum amounts of traditional medicines led to a scarcity of certain traditional medicine crops that had been widely available in 2010 and even in 2020. However, the active ingredients in these plants were identified, and they are now being produced on a massive scale using biotechnology techniques.

The ever-expanding health crisis in South Africa, particularly related to diseases of poverty including HIV/AIDS, TB, malaria and cholera, gave energy to efforts to develop drugs and vaccines, largely fuelled by donor funding since the poor are not able to afford

expensive medicines. Localised drugs and vaccines were developed for the South African population for comparatively little capital investment in the following way:

- The GPG convinced the research community (both public and private) to pool research data at the national level. The data were interrogated with a multitude of mining tools and methods to identify characteristics of the population and their response to drugs. In this effort all aspects that could influence the drug response equation were taken into consideration, from genetics to physiology and beyond. Thus became available the first ever actual response profile of the South African population to drugs, stratified according to sex, age, and other relevant factors..
- Existing drugs that appeared not to work in certain groups were analysed, and the factors which prevented the drugs from being effective in these groups were identified. For instance, cutting down the dosage of a drug for children is not always effective due to their metabolic status. Some drugs lack a co-factor that is required for effective action in children.

By 2030 the concept of "personalised medicine" was a reality. People were typed at birth and then treated throughout their lifetime to avoid triggers for the diseases for which they carried a genetic predisposition. Individuals who wanted to have this typing done, but who for economic reasons were not typed in their own countries at birth, were a constant market that flowed into Gauteng.

On a different front, crime was an ongoing problem in Gauteng given the high levels of poverty. The development of rapid genomic profiling and diagnostic kits, as well as transgenic biosensor bacteria with far more olfactory sensitivity than police dogs, led to a complete paradigm shift in crime investigation, even internationally.

Rapid genomic profiling enabled a unique genetic fingerprint of an individual to be generated routinely and from a minute sample of tissue or body fluid. Everyone was required to have their profile recorded and entered in their ID book and in national databases. This allowed for crosschecking against evidence from a crime scene, where rapid diagnostic techniques would be used by police to immediately gather detailed information. In addition, transgenic biosensor bacteria were developed that would

produce light or change colour in the presence of a certain compound.

There are now biosensors everywhere. Society is monitored at a level where accurate GPS-based locations are available in real-time for every single individual. Retinal scans at doors and entrances to buildings are commonplace. Fingerprint detectors on walkway handrails and stair handrails can identify an individual in a nanosecond. Whenever garbage is thrown away, a sensor detects fingerprints on items such as soda cans, and uses the sweat in the fingerprint to generate a genetic profile. Dandruff that is left behind on a chair back is also used for genetic fingerprinting. In this manner, individuals are tracked wherever they go, and crime is controlled, as it has become extremely difficult for criminals to move around without leaving a trail of genetic evidence.

The technologies that accomplish the above operate at the nano level, and sensors are monitored nationally and even internationally via computers that were developed to keep track of the massive volumes of data generated.

Biotechno9logy also played an important role in the food sector. Given the challenges of ensuring adequate nutrition for the poor, biotechnology was harnessed both to produce food additives (vitamins, minerals, amino acids etc.) as well as to develop genetically-modified crops with enhanced nutritive value (at both the micro- and macro-nutrient levels). GM technology was advanced to the point where release of genetically-modified indigenous crops such as sorghum and millet could safely be undertaken.

Prior to 2020, crops for medicinal use were cultivated on a much different scale and level than during the 2020s. With new technologies the crops were bred to be small in size but extremely high in nutritive value, leading to the production of crop mass that had an extremely high nutrition-to-size ratio. Some of these crops are at the microscopic level, but yet yield sufficient active substances to be effective for treatment.

Dealing with waste was always on the agenda of the GPG, and in this area as well, biotechnology was brought to bear. Microbial technologies and enzymes were employed to recycle waste materials that had been collected and separated to facilitate the use of

tailored recycling technologies. Organic waste was used to generate gas for heating and cooking purposes. At the individual household level, systems were introduced for recycling and energy production purposes. Other approaches employed included:

- Degradation of next generation plastics (biopolymers)
- Microbial and enzymic degradation of paper waste
- Enhanced mechanisms for sewage treatment
- The production of biofuels.

The population of Gauteng continued to increase, although there had been a lull in the aftermath of the financial crisis. The strain on Gauteng's infrastructure became more and more evident, but now, in the context of the fallout of the failed knowledge society strategy, the GPG did not exercise the leadership that they had done in earlier years. Signs of reaching breaking point were noticeable in many areas (e.g. sanitation, energy, roads) but once again it was the water shortage that held centre stage.

By 2025 even the significantly improved industrial and household water systems that had been implemented in the previous decade could no longer cope with the growing demand for water by the population of now 12 million people, along with a mining industry that continued to boom. . The populace had become wearily tolerant of water rationing for 2 to 4 months in bad years, but then two full years of drought in 2023 and 2024 led to rationing for a whole year. This proved too much for even the most patient. Public protests took place in various forms, often accompanied by violence from unruly elements.

Permanent water rationing, affecting 12 million people, was introduced in Gauteng in 2028. In 2029 the crisis reached a breaking point. Serious civil strife erupted. The Government was forced to choose between household usage and industrial usage. Out of fear of further civil strife, they placed the most onerous restrictions on the mining industry, which cried foul because of the huge investments that they had made in water systems, at the government's insistence, during the previous 10 years. They argued that the Government had not kept their commitment, made in 2019, to cap the population in

Gauteng below 12 million. Repeated legal action ensued, in which the mining industry was usually successful. However the conflict did not abate. It has damaged seriously the much-vaunted public-private partnership relationship in South Africa, with severe impact upon FDI, and on South Africa's international image. It has also undermined the credibility and effectiveness of the Government as it has resurfaced at regular intervals, tending to dominate our political discourse.

In response to this extreme water crisis a number of interventions were made:

- Halophilic microorganisms as well as plants were used to concentrate the salt. This was done at the coast before pumping the water up to the Highveld. A lot of bioprocess engineering was involved to get this to work effectively.

  Via bioprospecting new microorganisms were discovered that use salt as a major driver of their own metabolism. These microorganisms convert the salt to usable byproducts, and thus have a dual benefit.

- Succulent farms were established around Gauteng, and also just outside Gauteng itself, to capture water and to provide nutritious, edible succulents. This required genetic modification of the chosen succulent varieties to enhance their nutritive value. Every square metre of available ground in people's gardens was planted with succulents, where possible.

  Apart from the succulents, a range of crops were used that had been genetically modified for drought tolerance. Regulations were put in place to prevent farmers planting water-hungry crops, and irrigation was not allowed. In general the area under agriculture in Gauteng was reduced, and agriculture was much more intensive than it used to be.

- Like carbon credits, water credits become an important part of our lives. Everyone started trying to be water neutral as well as carbon neutral. Water credits could be traded for other services, and a whole water credit economy began to evolve.

- Water credits could be earned by developing and/or implementing waterless technologies such as waterless showers, waterless cleaning methods, waterless laundry etc. Microorganisms that "eat" dirt were used, with a minimum of water. Enzymes that operate in organic solvents became important.

  Waterless biotechnologies include the characteristics of new materials that were developed where the surface of the material itself acted as a 'cleaner'. I.e. dust could simply not settle on the Dust-Buster-Plastic that was developed for eyewear. The surface of the glasses would be a micro version of Teflon where in this case dust could not stick to the plastic glass surface. The technology was at the nano level, as the plastic was engineered to be super smooth.

- At both individual and community level, water was captured and recycled. Highly efficient biological recycling mechanisms were put in place to purify the water. Microbes attached onto solid substrates were used to filter the water effectively. Biofilm technology became highly developed. Microorganisms were developed whose faster growth was triggered by the electrical potential in the water.

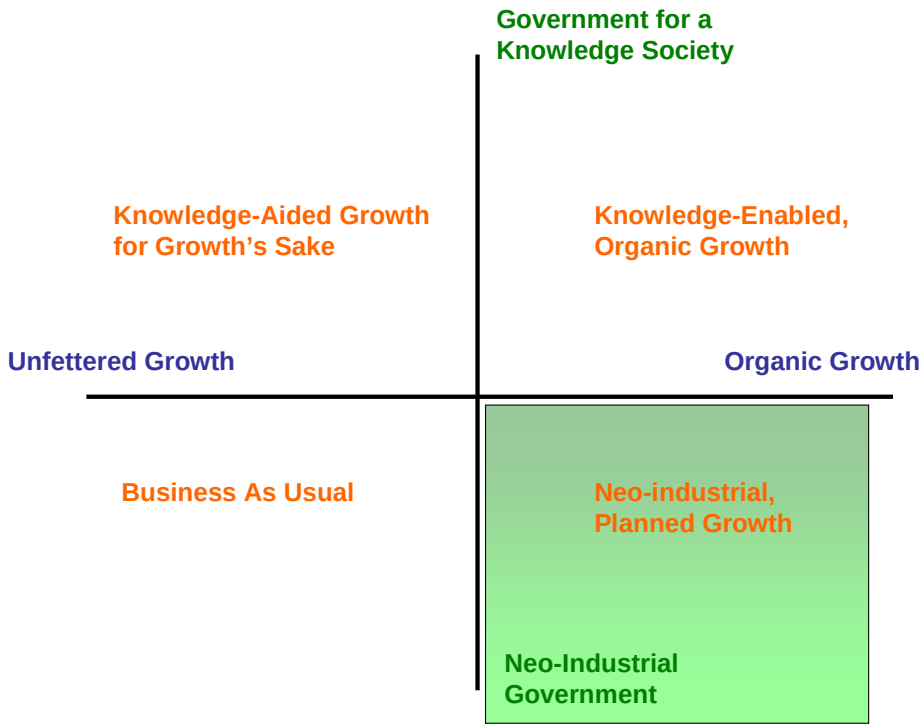
- Most of our manufacturing moved towards minimal water usage. Technologies such as solid state fungal fermentation for manufacturing a range of products became commonplace. In solid state fungal fermentation, fungi are grown in trays or in rotating drums on solid substrates such as crop residues (straw, tree bark, maize stover etc.) with some added nutrients such as sugar, oil etc. A wide range of products can be produced e.g. flavours and fragrances, pharmaceutical compounds, agricultural growth promoters (any fungal metabolite).

- Water quality issues had to be addressed in all areas (e.g. industry and household). Closed systems were required. For the household, small-scale bioreactors for water purification were promoted. Biofilters and biomembrane technologies were essential, as well as wetland remediation. On-site artificial wetlands for the remediation of heavy metals etc. in mine waste was one example. Groups of

companies began moving towards pooling resources and centralising waste reclamation.

Hand in hand with pollution control, sophisticated biosensor technologies for pollution monitoring were implemented at all levels of society. This included rapid dipstick tests as well as flow-through monitoring systems for industry.

Scenario 2: Biotechnology in the Context of Neo-industrial, Planned Growth



The years: 2009 to 2019

The Gauteng Provincial Government (GPG) was very growth oriented, but they recognised the need for organic, balanced and equitable growth if it was to be sustainable and avoid social dysfunction. Their vision was to create a prosperous and equitable Gauteng through the execution of carefully-conceived development plans.

In 2009 the (new) national Government took the strategic decision that the key to a better future for all South Africans was the establishment and development of a knowledge society, at all levels, in the country. There was only minimal support in the GPG for this approach of the national Government, and they argued that it should be phased in, and that Gauteng should not be actively involved until the relevant

mechanisms had been tried and tested in other provinces. The knowledge society approach was far too amorphous in their view. Such an approach would allow the GPG insufficient control to achieve their goals for Gauteng. The national government reluctantly conceded that, with so much depending on the success of Gauteng's economy, 2010 may not be the best time to experiment.

The GPG followed a strict top-down approach to achieve equitable growth and development, using a tight-loose-tight management style. Each department was given clear targets and expected to attain them. In practice, each department went off independently and put policies and programmes in place without consulting colleagues in other departments. What on paper were good policies in areas such as alternative energy, town planning, rural development and education, proved a nightmare in practice because there was no integration between them or coordination in implementation. The lack of transparency was marked.

Nevertheless, the GPG brought much energy to executing their development plans, and they had the financial resources to make things happen. However, their approach was control-oriented. They spoke of entering into partnerships with the private sector, but in practice these were unequal partnerships with the GPG wanting to call the shots. Their relationship with big business suffered as they tried to get major companies to follow policies in the name of 'organic' growth that made little business sense in the short term. As for SMMEs, after an initial attempt at harnessing SMMEs as part of their development plans, the GPG decided this approach was a lost cause. Those SMMEs that complied with their instructions were hopelessly inadequate when it came to delivery, while SMMEs that had good experience and capacity were reluctant to toe the "top down" line and were constantly motivating for significant changes in the GPG's plans.

Throughout this period, the GPG maintained a strong emphasis on the role of BEE in achieving socio-economic equity, and it was included as a core component of every development initiative. The GPG viewed many private sector organisations as merely paying lip service to the BEE concept, instead of adopting its spirit, and their relationship with many big businesses deteriorated even further. It also proved

particularly difficult for many knowledge intensive business services (KIBS)-oriented SMMEs to meet BEE requirements due to the historical shortage of appropriately qualified black people, and hence more and more chose to provide their services in other African countries.

Over time, the GPG also lost patience with Gauteng's academic sector, given their image of being elitist, "old guard", and self interested. Although in the early days inputs were sought from many academics, their growing level of criticism of the GPG's development approach amplified the lack of empathy and trust between the two sectors. The GPG was inclined to neglect most critical inputs from the academics, no matter how well their research was reviewed internationally, because they did not trust their motives.

Given its wish to turn Gauteng into a "green" province, the GPG decided to make a major impact in renewable energy. There were few opportunities in Gauteng's mostly urban and comparatively restricted open spaces for wind farms or hydro-electric power. At a national level, nuclear power was receiving a lot of attention, but because this was a national-level initiative the GPG felt that they lacked sufficient influence and control. So they decided to focus on urban solar power, while paying lip service to the importance of the national focus on the nuclear option.

Solar power held great promise in Gauteng due to the large amount of sunlight received by the province. The GPG worked hard on building relationships with international companies with established leadership and expertise in these markets. Initially there were promising results in converting some of Johannesburg's largest buildings to become energy independent. But cracks in the process appeared as relationships soured between the multinational suppliers and local distributors.

The first wave of local distributors, which were fairly small companies, were knowledgeable about the local circumstances in SA and pointed out that many of the imported products would not work sustainably without significant changes. But the multinationals wanted immediate sales rather than advice (especially from what they saw as a technological backwater), and employed alternative distributors who, because of

their lack of knowledge in the area, asked few difficult questions, and advised only on sales rather than on technology. The net effect was to under-exploit the potential of solar power in Gauteng, and, in the longer term, to stifle the growth of a local solar power industry.

Momentum was lost on the solar energy front, but energy security remained a key issue. So the GPG decided to target a seamless transition to nuclear power in Gauteng by 2030. Fossil fuels would not be used for generating power and nuclear power would be the main source of energy. Furthermore, concerns regarding nuclear waste were overcome by the use of extremeophiles. This breakthrough came in 2019 following targeted investment by the GPG's "Green Fund" supported by the Department of Energy and channelled through SMMEs which focused on the exploitation of natural resources, whereby a significant amount of knowledge about extremeophiles was gathered. This was utilised to process nuclear waste for the production of biofertilisers.

While this was being done, the Department of Environmental Affairs was looking at the production of electricity through the process of gasification. For this process, genetically modified, underutilised indigenous trees were produced through collaboration between the University of Pretoria and "Advanced Forestry Systems", a KIBS which was a spin-off from forestry experts at the University. Although these technological advances were significant, the lack of trust, communication and collaboration between the departments of Energy and Environmental Affairs undermined the rollout of these technologies to underserved communities. There was also duplication of resources and wastage of funds.

Another key issue for the GPG was the problem of dealing with the increasing waste that was being generated in the province, particularly as a result of the influx of population. In 2012, to combat this problem, GPG put out tenders for novel ways for dealing with waste. A BEE SMME "Waste for Africa", in collaboration with an overseas company, marketed and implemented an off-the-shelf technology solution to convert domestic waste into fuel, utilising genetically modified micro- organisms. In 2014, due to a lack of understanding of the applicability of a particular microbe to Gauteng's climatic

conditions, this technology failed. In addition, GPG was faced with eradication of this foreign micro-organism in the local biosphere. By this time GPG had stopped supporting this project and the SMME looked elsewhere in Africa for other organisms.

While not on the critical list, the GPG recognised the importance of construction, both domestic and industrial, for the continuing health of the province. They therefore supported research efforts into environmentally-friendly construction materials and processes. The emergence of early research results supporting environmentally sustainable construction, and that focussed on value addition to natural resources and the use of less damaging methods of production, led to the development of novel building materials. The first was biodegradable wood products for construction. These products were manufactured by genetic engineering of indigenous forestry species that had high cellulose content, and accelerated growth cycles. Further developments in the field of nano- and biopolymer technology led to the development of biodegradable polymers and materials that were less harmful to the environment. The re-engineering and design of new materials including nano- and microstructured materials also resulted in the development of "biofab" materials for construction, development of biodegradable and biocompatible polymers that could be used to make plastics for use in construction, and less harmful, organically-based adhesives.

Focussed research on the exploitation of microbes which naturally produce polymers to store carbon and energy yielded significant breakthroughs in the utilisation of bio-admixtures to add value to building materials. In particular polyhydroxyalkonates, produced naturally by bacterial species, proved to be a remarkable alternative source of polymers for construction materials. These polymers were the precursors of biodegradable plastics which decompose naturally and proved to be an effective substitute for synthetic plastics. Further benefits were gained when scientists were able to isolate the gene responsible for polyhydroxyalkonate production. They transferred the gene into plant systems so that transgenic plants producing polyhydroxyalkonates provided a rich source of natural polymers that could replace environmentally synthetic polymers in a range of industries. In addition to the production of transgenic plants, the identification and toll manufacturing of bioproducts such as pine root extract, guar gum,

tartaric acid, casein, and xanthan gum led to the development of a budding bio-admixtures industry.

In a parallel development Habitat International, recognising the lack of specific support from the GPG for construction-related SMMEs, undertook an initiative to stimulate local SMMEs in the sourcing and improved development of locally-produced housing materials. They looked at local species for high tensile strength in "biofab" materials, and combined this trait to produce photoharvesters to capture photons during the day and then release light during the night, using GM organisms. A further application was the use of organisms that purify the air in a building by absorbing the impurities and other gasses in the air and releasing oxygen as a by-product of the absorption process.

Early in the decade there had been widespread support from all levels for a research focus on developing and preserving Gauteng's dwindling natural resources. Consequently, this area was an early beneficiary of research support by the "Green Fund". In 2013 a remarkable and wide-reaching discovery was made in a peri-urban area outside Pretoria of a fungus with unusual properties. Following certain bioprocesses the fungus produced enzymes that had application in the pulp and paper industry, making obsolete the use of chemicals in their processes. Large scale production of the fungus commenced.

Another spinoff from this research was the discovery of novel aphrodisiacs from other fungi growing in old mine shafts. This stimulated partnerships with several Asia-Pacific countries.

These bioprospecting successes prompted further initiatives by the universities of Pretoria and Johannesburg, targeting indigenous flora and fungi in Gauteng and in other parts of the country. Several plants and fungi were identified as sources of new fibres for textiles, colorants and flavourants, and enzymes. Research was then undertaken into manipulating growing environments and conditions (moisture, temperature, pressure, nutrient source) to optimise the level of production of the product. This was followed by research to identify the genes responsible in the production of these compounds and

then to transfer them to organisms that could produce the compounds at economically-viable levels. For example, the genes for the production of a natural red dye by an insect (cochineal, an aphid-like insect found on prickly-pears) were taken and transferred to algae. The production of this dye by the algae was enhanced through genetic engineering. The dye is secreted into the growing medium, which makes extraction and processing more cost effective.

In another initiative, biocompatible natural polymers were produced through screening the vastly underutilised grasses and shrubs of the savannahs and plains on the outskirts of Gauteng. These plants were screened for high tensile strength, durability and stability when combined with natural dyes and colours that had been identified in other bioprospecting initiatives. This led to the re-emergence of the waning textile industry in Gauteng and these new textiles had considerable export potential.

Between 2010 and 2020 there was a growing market, both local and global, for nutraceuticals due to their healthy, organic and natural profile. This demand stimulated research, as would be expected, and one area of research that was promoted heavily by the University of the Witwatersrand was the application of metabolomics. There are probably in excess of 250 000 metabolites in the plant and fungal kingdom, which offers a potentially unlimited resource for developing nutraceutical products. Research was conducted in metabolomics focused on metabolite profiling, metabolite target analysis, metabolite quantification and metabolic fingerprinting. The results provided a significantly improved understanding of the physiological regulation of metabolic networks within plant and fungal cells. This enabled a focussed and targeted approach to the production of a range of particular nutraceutical in large quantities, with a short production cycles. A significant nutraceutical production industry emerged.

Generally, the GPG's drive to make Gauteng a "green" urban province focused on a "leap-frog", technology-push approach. It did not extend, as many researchers advocated, to investigating all aspects of Gauteng's carbon footprint, and particularly the urban province's current and future impact on the rural environment, near and far, which is its primary source of such resources as food, water, energy and manpower. A case in point

was their reaction to the water crisis which surfaced in 2015. An investigation by overseas experts highlighted several areas for improvement (some of which were questioned by the "untrusted" local experts) which could ameliorate the problem, at least in the short term. Excellent plans were drawn up based on these recommendations, but in practice their measures were poorly implemented by uncoordinated departments with little relevant expertise. So water shortages continued to occur at regular intervals through to 2030.

In 2016 Gauteng suffered a financial crisis. Many South African banks had strong ties to banks overseas, and this was certainly true for ABSA in which Barclays had a strong interest. Through a series of ill-considered actions and unforeseen circumstances (which brought memories of the financial crash of 2008) Barclays ended up in a precarious position and had to be propped up by the British government. This sent shockwaves through South Africa's banking industry in general, and through ABSA in particular. What aggravated the situation was that certain sections of ABSA had been operating outside of company guidelines, and the result was that they overextended the bank by lending money to people who were unable to afford the loans. ABSA was liable, and this combination of circumstances resulted in a run on ABSA's money. Depositors withdrew their savings in droves, and ABSA started to topple. The situation was rescued by a buy-out by a Dubai-based bank, who in short order moved top management control of what had been ABSA to Dubai. In addition, they moved ABSA's listing to the Dubai International Financial Exchange (DIFX).

The GPG lobbied the national Government to intervene, but there was no agreement as to what the nature of the intervention should be. A wide-scale and wide-ranging debate ensued, characterised by more heat than light. What did become clear were the fundamental differences in outlook that existed between the national Government's knowledge society approach compared with the GPG's neo-industrial approach. Eventually, after four months, a compromise was reached, and the national Government agreed to intervene, but by this time it was a case of too little too late.

ABSA's move from the JSE had had a knock-on effect a few months later when several other financial services companies, attracted by the benefits that erstwhile ABSA was enjoying, also moved to the DIFX. In the hiatus that resulted from the disagreement between the GPG and the national Government, this trickle turned into a flood, and by the end of 2018 the number of companies listed on the JSE had dropped by 15% (the figure was 35% for the financial services sector), and more than half of the companies that moved had above-median turnover (as determined in 2016).

The scale of the financial crisis was such that Gauteng's economic growth was flat to negative in the last three years of the decade. The loss of jobs was a social disaster for the province, and in 2019, for the first time in living memory, there was a net outflow of population from the province.

Many large biotechnology companies made an exit from Gauteng due to the financial crisis, and this led to a gap in the market, which created opportunities for SMMEs. This was particularly the case for the development of a growing nutraceutical industry based on the knowledge gleaned from bioprospecting of indigenous floral and fungal species.

The years: 2021 to 2030

In the years immediately prior to 2020 there had been a heightened awareness of the need for securing the nation's food supply, due to increasingly-erratic and drier weather that had wreaked havoc with agricultural production. Gauteng, with its large population, was most threatened by this trend, and so early in the 2020s effort and energy began to be devoted to addressing this issue. Due to space constraints in the province for growing food, the GPG investigated alternate food production strategies. Soil-less production systems were investigated, using plant organ culture and growth of GMO crops, engineered with shortened growth cycles.

The first step was to shorten the growth cycle of the plants through traditional breeding, as well as genetic modification. This resulted in plants that grow fast and produce food in a shorter period of time then traditional strains. However these plants had a heavy

nutrient requirement and were vulnerable to attack from insects and other pests because most of the plants' energy went into production with little available for defence mechanisms to protect the plant from disease. The best way of overcoming this problem was to grow these crops in controlled environments in a soil-less system which could use other materials such as coconut fibres as a growing medium. An alternative was a system using water as the carrier of the nutrients to the plants, with no other growing medium. In these growing facilities the atmosphere and temperature were optimised for production, and high levels of management meant that disease control was highly effective.

By 2030 all traditional food crops had been genetically modified. In 2029 the results of a five year survey of nutritional values of indigenous plants was published, and several new food sources were identified. The popularity of these novel foods led to continent-wide and international publicity, and an external demand was created. So these novel foods were exported to the rest of the African continent and to the East.

Many indigenous crops had been modified to be drought tolerant. Other crops had improved herbicide and disease tolerance. The beneficiation of indigenous cereals with improved nutritional quality, higher levels of vitamins, improved digestibility and shorter growth cycles, led to the establishment of a stronger agricultural market. Emerging farmers were supported to establish hydroponic, controlled environment "farms" in marginalised areas, and small entrepreneurs built compact, modern bio-processing and packaging plants for food processing. Products were formulated for improved shelf life, enhanced flavourants, wider consumer acceptance and affordability. Although the province had previously relied on sourcing agricultural products from outside the province, it was now becoming fully sustainable in terms of food requirements.

Looking back, the GPG's success in securing Gauteng's food supply was unexpected, especially given the climate of opinion that has existed in the province during the 2020s. In 2021, a joint report by the World Bank and the EU entitled "The Emergence of the Knowledge Society in the Developing World" provided an in-depth chapter on South

Africa's approach in general and Gauteng's results in particular. The report praised the GPG's genuine desire and commitment to promote organic development, but highlighted the mistakes associated with their reluctance to adopt the national Government's preferred knowledge society approach. The report went into some depth to provide evidence that after ten years, the GPG's retention of a rigid hierarchical government structure had failed to successfully implement what the authors judged to be mostly well-conceived strategies. The report further pointed out that the top-down approach of many GPG departmental silos, despite the emphasis on shared policies and approaches, actively prevented an integrated, coordinated approach, leading to much duplication and waste. The report voiced concern that the use of monitoring and evaluation merely to "tick off" what had been done, rather than to attempt to measure any longer term impact of the initiatives, meant that little learning could be gleaned from ten years of significant investment of people, funds and expertise.

This report revived local criticism, particularly from the local researchers and experts, but with growing support from the SMME sector and the poorest communities. However, the longstanding distrust between the GPG and the academic sector made it hard for the government officials to back down. Instead, they continued with their approach, with a few cosmetic improvements, and in 2024 a public relations campaign was launched "to create better understanding by the ordinary man in the street of the extreme challenges faced by the GPG, and its substantial achievements to date". This expensive three-year exercise convinced very few, even within the GPG, and the widespread disapproval eventually ruined many promising public sector careers.

In 2028, following a substantial purge of staff (some of whom were later seen to have been innocent bystanders, with valuable expertise and experience) the GPG at last recognised that their development strategies were failing. But instead of identifying the cause as being their inappropriate neo-industrial structures, they found fault with the organic growth approach, which was then abandoned. There was universal criticism of this decision, which simply entrenched the polarisation between the various sectors of society that had developed over the previous 20 years.

A particularly sad note: a bloom of SMMEs were beginning to emerge at this time in a delayed response to the well-devised strategies of the GPG, despite their dysfunctional structures and implementation plans. But the abandonment of the organic growth strategy, and the polarised sectoral conflicts, meant that most of these SMMEs simply faded away.

On a different front, a water crisis had been growing in Gauteng during the teens, due to the increasing influx of people, and higher levels of industrial activity. Attempts had been made to improve the water infrastructure in 2015, and experts predicted that a major crisis would hit the province in the early twenties, on the assumption that current levels of economic and population growth were maintained. The financial crisis rendered those assumptions invalid. Throughout the twenties the population remained static or decreased, and so ironically, the disaster caused by the financial crisis meant that Gauteng avoided what would possibly have been a worse one: running out of water. Nevertheless, the lack of water was a constant threat, and the periodic droughts that were an increasing feature of Gauteng's climate resulted in the recurring imposition of water restrictions and attempts at reducing water consumption.

These recurring water shortages had severe implications for vulnerable ecosystems in the tourism sector of Gauteng. Many mammalian species such as the Gemsbok, Kudu and Burchell's Zebra moved onto new terrain in adjacent provinces, which made it increasingly necessary to devise methods for tracking game. As a means of monitoring cross-border movements of game, molecular markers from Gemsbok, Kudu and Burchell's Zebra were collected in a gene bank. Because these populations were sourced from endemic malaria areas, these gene banks were analysed to identify the genetic component for malaria resistance. Common alleles were found to occur across species and this opened up the possibility of DNA therapy for malaria infection.

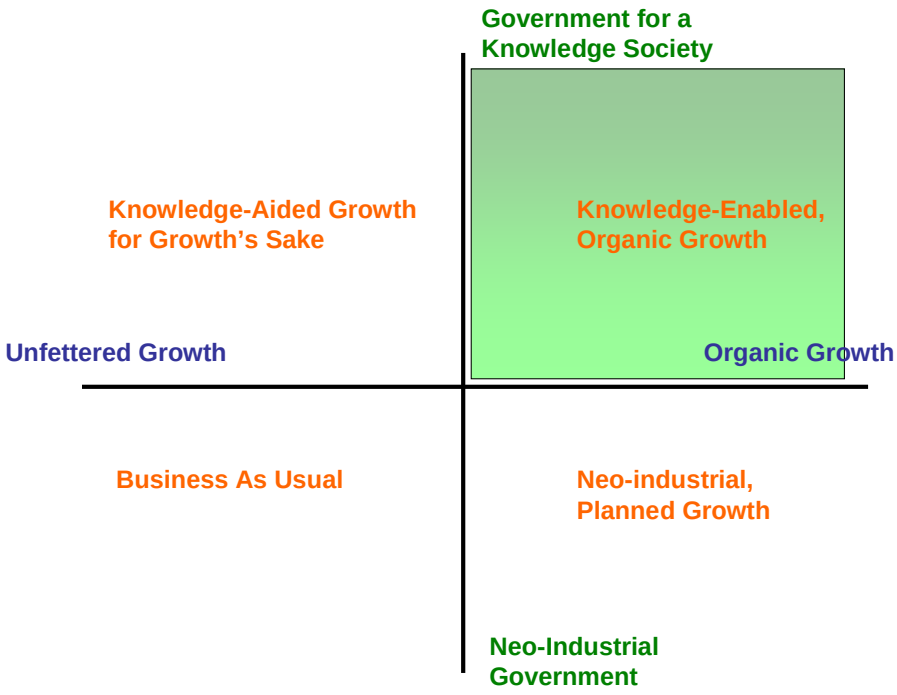
The veterinary research institute at Onderstepoort, along with the universities of the North West and Witwatersrand combined their resources to develop the fauna gene bank. After completing the elucidation of the genomes of all these mammalian species, genes encoding specific proteins were predicted using bioinformatic analysis. Concurrent

research into the cellular and molecular basis of malarial infection in the human population in these areas, and the use of DNA microarrays for biodefence-related diagnostics, led to the discovery of alleles that were not present in the human population but were present in the fauna mammalian population. These selected genes were then either cloned into other host expression systems or *in vitro* for the directed production of useful proteins. Further analysis of these genes using pathogenicity testing against a range of biodefence-related molecules, and screening in high throughput mammalian cell culture systems, yielded a combination of proteins that had the potential to be antimalarial, with the possible application in gene therapeutic products. The establishment of successful and robust mammalian tissue culture techniques, coupled with improved protein scaffolding post translation, enabled a significant increase in the production of quantities of proteins that could be selected by cell surface display, and later be used for gene therapy applications.

Scientists were able to use enhanced delivery mechanisms to targeted cells in conjugation with carrier molecules and the use of gene therapeutic products in order to treat malaria in parts of the human population affected by this deadly disease. Within a short period the use of gene therapeutic products replaced the use of chemically synthesised drugs. This was a significant breakthrough, since the high incidence of malaria as a result of multidrug resistance to antimalarial pharmaceutical products was now something that could be controlled with the new treatment, resulting in fewer fatalities. Furthermore, the later increase in incidents of malaria due to rising temperatures in Southern Africa related to climate change could be combated more effectively.

Gauteng now has the opportunity of coming up with a long-term solution to its water supply needs, without the immediate crisis caused by a lack of water. This in itself is good news, but the wider implications are not as cheerful. The prospects of economic growth in the short term are bleak, and the experts say that fundamental changes are necessary to enable growth in the medium term. The dilemma is that there is no agreement as to what the changes should be.

Scenario 3: Knowledge-Enabled, Organic Growth



The years: 2009 to 2019

The Gauteng Provincial Government (GPG) was growth oriented, but not for its own sake. They sought mechanisms which would provide balanced long-term growth that would also be sustainable and avoid social dysfunction. Their vision was to create an equitable Gauteng without sacrificing (too much of) its prosperity. Many viewed the implementation of this vision as unfeasible and accused the GPG of being too idealistic, or dogmatic, or both.

In 2009 the (new) national Government took the strategic decision that the key to a better future for all South Africans was the establishment and development of a knowledge society, at all levels in the country. It was agreed that the first phase of this strategy would be implemented at the provincial level. Significant insights were

anticipated by a two pronged approach, involving Gauteng (being the most economically advanced province), and the Eastern Cape (which was severely under-developed).

The GPG quickly embraced this strategy, deciding to facilitate the development of knowledge organisations and the adoption of knowledge-based processes and practices across all sectors and levels of society within Gauteng. This committed the GPG to transform itself not only in the way it delivered services, but especially in the way it operated within and between its many departments. This proved to be no easy task.

Especially during the initial stages the task of getting departments to willingly work together effectively and efficiently appeared to be almost impossible. Whereas most government officials were forthcoming in identifying flaws in and suggesting improvements to the processes and practices of other departments, they often became defensive at the suggestion that there might be similar flaws in their own. The entrenched culture of blame and risk avoidance, and the resultant covering up of mistakes and rejection of innovation proved a significant barrier to the adoption of open learning from mistakes that characterises the knowledge society. However, through innovative and dogged leadership, and the example set by a few early successes, the tide began to change and, despite many pockets of resistance, the commitment to learn, relearn and genuinely transform government became more and more widespread and persistent.

Perhaps the most tangible indicator of the willingness and commitment to transform in the first few years was the variety of mechanisms used to ensure that as many stakeholders as possible became actively involved in the long-term, rather than being used in cosmetic participatory processes.

Nevertheless, progress in transformation continued to be slower than anticipated. It was not uniform, but piecemeal, often occurring in fairly small groups within departments, and sometimes between officials with common goals working across two or more departments. In these circumstances, a common feature was that pockets of mutual trust developed which, in turn, transformed communication. Such groups tended to be

more productive, and, although usually feeling over-loaded, appeared to enjoy their work.

Since the drive to transform was taking place in Gauteng at both the provincial and local levels, some examples of significant improvement to the interactions between these levels began to emerge, associated with the pockets of progress. In contrast, interactions often became even more problematic with the national level of government, which had decided to delay any transformation until it could gauge the results from the provincial level. An example of this disjoint was the lack of coordination concerning housing. Whereas the national government wished to push on with a "mass production" approach to delivering houses, the GPG, influenced by its active stakeholders from communities, research institutes and industry, was intent on giving potential homeowners choice and flexibility, introducing environmentally-friendly designs and construction methods, and involving local communities in the process of planning and implementation. The confusion and paralysis that resulted from this disjoint caused a slowdown in building houses that pleased no one.

The difficulty of measuring the impact of the slowly evolving transformation process is revealed by the complexity of its effect on initiatives aimed at sustainable poverty eradication. GPG departments that were resisting their own transformation, and persisted with the old "top-down" approach showed early success in projects in poorer areas. Only after three or more years did it become clear that most of these projects would not be sustainable, primarily due to the lack of community involvement and ownership.

By contrast, most GPG departments that were undertaking the transformation process to become more knowledge oriented showed little early success in such projects. Their efforts appeared more disorganised as they experimented with ways to involve communities and ensure ownership at the grass-roots level. Their focus on their own internal transformation usually left them slow to follow up on development projects, which inadvertently had a positive outcome regarding sustainability. Communities that were waiting on departments to follow up on initiatives had nevertheless been given a

clear message that they were now empowered to be active agents in their own development. So they used the delays and waiting periods creatively, getting their own acts together, and even developing their own initiatives. And despite the delays, there was definite improvement in trust and mutual learning between the communities and the transforming departments.
By 2019 it was becoming clear that the level of transformation being attempted by the GPG could not and would not be achieved anytime soon. Those departments that appeared to have moved furthest on the path to transformation seemed most certain that they had not yet reached their goal. Indeed, some argued that the goal was not a "final fixed state of transformation", but the ability to continue to change in response both to current realities, and to a shared vision of the future. It seemed likely that there would be many more waves of transformation efforts to come.

The pockets in the GPG where sustained progress with transformation seemed to be taking place were displaying some common characteristics. They were usually less hierarchical, more interdependent, and more horizontally connected (including interdepartmental collaboration), with a pragmatic grasp of futures intelligence processes. They recognised their primary role as facilitators, rather than as implementers, and they promoted and implemented in practice transparency and increased trust, as well as working collaboratively with other government departments and all stakeholders. Another finding that was causing concern to some government employees was that the transformation process was revealing that certain long-standing processes, and even departments, were no longer necessary, since they could more efficiently and effectively be handled elsewhere.

During the GPG's transformation, an area of facilitation that they handled well was in the promotion of the role of technology in developing a knowledge-based society. This manifested in technology-rich solutions being applied in a range of sectors, with biotechnology being particularly prominent.

In the manufacturing sector, biotechnologies were applied to develop advanced manufacturing processes, which migrated in time towards smart manufacturing. There

was convergence of disciplines, e.g. bio-microfluidics, and the development of mobile manufacturing systems, which resulted in new opportunities, and accelerated the transition to smart manufacturing using smart technologies. Centres of excellence in advanced manufacturing were established, focused on enzyme-based manufacturing, diagnostics and cell reactors, and GMOs.

Enhanced opportunities were created through, for example, the use of biotechnology in the mining sector, that resulted in discoveries that were beneficial in the health field. For example, smart microorganisms that were designed for the mining sector were subsequently used by the healthcare system for the detoxification of chemicals in the bloodstream.

A socio-capitalistic system was emphasised that supported a distributive model where the benefits were spread to the local community and its environment. This included encouraging a culture of entrepreneurship. Factories were moved to where the raw materials were, namely to the rural areas (after extensive consultation and collaboration, and sometimes beyond Gauteng's borders) so that people could be employed where they live. Household "living labs" were encouraged. There were incentives for people to manage their resources in an integrated fashion, including producing their own food, and processing their own waste using biodigesters.

Significant progress was made in the food sector in Gauteng. A reorganisation of government in this area resulted in the establishment of a Department of Sustainable Development that brought a horizontal, flat structure to an area that was previously characterised by many isolated government 'silos'. This greatly increased communication and exchange of information between entities that previously had no knowledge of each other. More specifically, the testing and deployment of GMO-type foods was dramatically speeded up. Additional resources were made available for research; considerable R&D was expended on single cell protein (SCP) as an alternative source of protein.

In the private sector, the most obvious impact of the GPG's aim to create an equitable knowledge society was seen towards the end of the decade in the growth of SMMEs, both

in the formal and informal economies. A flourishing sub-set of these SMMEs were delivering knowledge intensive business services (KIBS). There were two distinct types of these KIBS-oriented SMMEs: those that were helping the GPG with investigation and implementation of its policies and strategies across all sectors; and those emerging in the informal economy in poorer areas.

The government (national, provincial and local) was faced with a serious dilemma in its wish to stimulate these SMMEs, particularly in the informal sector. There were a large number of rules and regulations either inherited from the past, or imposed from the international community which stifled the development of many SMMEs. Especially for the informal sector, the government took a circumspect approach. It maintained a strong "no tolerance" approach to all forms of serious crime (although there were many heated debates regarding what constituted "serious crime", which remain unresolved in 2030). However, it practiced a "high tolerance" approach for infringements of minor rules and regulations by new SMMEs until they were on a secure financial footing.

The government encountered two areas of strong resistance from within South Africa to their "high tolerance" approach. One was in the area of environmental rules and regulations, which many argued needed to be strengthened rather than weakened. The government quickly "ring fenced" all aspects of the environment as a "no tolerance" area. The second was from large companies (especially multinationals) who felt the government was allowing SMMEs to become too successful before enforcing the rules and regulations. This remains a grey area in 2030, to the benefit of no-one other than South Africa's legal profession.

In 2016 Gauteng suffered a financial crisis. Many South African banks had strong ties to banks overseas, for example Barclays had a strong interest in ABSA. Through a series of questionable actions and unforeseen circumstances (which brought memories of the financial crash of 2008) Barclays ended up in a precarious position and had to be propped up by the British government. This sent shockwaves through South Africa's banking industry in general, and through ABSA in particular. What aggravated the situation was that certain sections of ABSA had been operating outside of company

guidelines, and overextended the bank by lending money to people who were unable to afford the loans. ABSA was liable, depositors withdrew their savings in droves, and ABSA started to topple. The situation was rescued by a buy-out by a Dubai-based bank, who in short order moved top management control of ABSA to Dubai. In addition, they moved ABSA's listing to the Dubai International Financial Exchange (DIFX).

Although unwelcome, this crisis did not come as a complete surprise to the GPG. For several years they had been investigating the opportunities for providing (micro-) financial support to emerging SMMEs in the informal sector. Research during this investigation had sensitised the GPG to several vulnerabilities among Gauteng's financial institutions. In response, the GPG held a series of high-level workshops in 2014-15 involving global experts and stakeholders to discuss Africa's financial needs and stability. During this process, a strong relationship developed between the GPG and Dubai, since it became clear that the Emirate shared South Africa's ambition to become a mainstay of Africa's financial capacity in what was hoped to be a much more successful African future. The 2016 crash created the opportunity to accelerate the development of this relationship, since Dubai recognised the experience that ABSA, and the JSE had gained of working in Africa.

ABSA's move from the JSE had a knock-on effect a few months later when a few other financial services companies, attracted by the benefits that ABSA was enjoying, also moved to the DIFX. However, the collaborative relationship between Dubai and the GPG prevented the trickle from becoming a flood, and by the end of 2018 the number of companies listed on the JSE had dropped by only 6%.

Gauteng's economic growth during this decade was modest, especially in comparison with the previous decade, and in the two years following the financial crisis, there was recession. Although there was a constant influx of people to the province, the rate of population growth was much lower than that which had been experienced during the first decade of the century. Even so, Gauteng's infrastructure showed signs of strain under the increasing population, with the water supply for the province being a particular point of concern. The GPG implemented a range of measures to discourage

population increase. In addition, the problem of water leakage and loss in the distribution and storage system was tackled with vigour. Apart from two periods of severe water shortage, water restrictions proved to be unnecessary during this decade.

By the end of 2019 there were definite signs of economic recovery, and the collaboration that had commenced with Dubai became one of the province's strengths.

The years: 2021 to 2030

At the dawn of the twenties there was evidence that the strategy for building a knowledge society was just starting to work. This evidence was provided mainly by bottom-up initiatives that were owned and driven by local communities, with strong support form the GPG. At the same time, it was easy to point to unproductive, and even chaotic areas where little movement, let alone progress, was evident. The national Government was becoming increasingly frustrated at the slow progress and wanted the GPG to act in a more decisive and top-down fashion. In response, the GPG arranged an international conference on the knowledge society, at which they presented what had been achieved and not achieved, and the issues and challenges that were being dealt with. As might be expected, there was much that could be criticised, and several global experts did not hold their fire. But the surprising consensus of the global participants was one of being impressed with what had been achieved. This stamp of approval was significant enough to satisfy those in national Government who had been critical of the GPG.

In 2021 the GPG ramped up to a higher level their support for informal learning opportunities. In the previous decade they had spent much energy in trying to reform the education system in the province, and make it more suited to a knowledge society, but results had been poor. So they now started encouraging informal learning through SMMEs and community organisations. People had the opportunity to learn what they wanted, when they wanted, and at the pace that they wanted. A range of multimedia-based ICT learning tools were developed and used, but there was also an emphasis on learners having access to relevant human expertise. In other words, learning was aided through interaction with both technology and mentors.

Also in this decade, the focus on triple helix collaboration (between tertiary educational institutions, and the public and private sectors) began to show real fruit. Levels of trust between people in these sectors had grown enormously. Local researchers were being used increasingly in advisory roles, while research agendas were more and more focused on problems in industry. It was true, however, that most of the collaboration by the private sector was driven by SMMEs, not big business (the latter were more comfortable with an organised, top-down approach, rather than free-for-all networking and collaboration).

The collaborative model espoused by the triple helix approach, with enthusiastic participation by SMMEs, was exemplified by stakeholders in the health industry. Much innovation was evident, stimulated by the trend towards increased responsibility by the individual for his or her own health. Thus personalised health monitoring became more important, and this was supported by the development of new diagnostic and therapeutic products, usually based upon biotechnological innovations.

Due to the genetically diverse population, it was necessary to account for the ethnic differences in the susceptibility to various diseases. These included for example cardiovascular diseases (hypertension, cardiomyopathy), diabetes, cancer and neurological diseases. Genetic profiling therefore became an accepted practice.

Biomarkers were used in routine clinical care for the selection of the most appropriate and effective therapeutic agents for the treatment of the disease in question. Therapeutic responses were monitored in their initial phases by alterations in the levels of biomarkers prior to overt modifications in the disease itself. Biomarkers, in the forms of protein or genetic markers, were also used for prognostic and diagnostic purposes.

Based on genetic profiles, which predict the physiological consequences of the interaction between genetic susceptibility to disease and the environment, specific recommendations could be made with regard to dietary intake.

Vaccines, in the form of DNA, RNA and protein, were used both prophylactically and therapeutically. The entire population of Gauteng received effective vaccines against all major infectious diseases. The vaccines were administered to all neonates through a routine childhood vaccination programme. For cancers where the etiologic agent was known to be infectious (e.g. HPV in cervical cancer), neonates were routinely vaccinated as part of a provincial programme, which was soon adopted at the national level. Therapeutic vaccines were administered to patients in whom the presence of specific molecular targets had been identified. Vaccines targeted at cellular components of, for example, atherosclerosis, were used in susceptible individuals. Vaccines were also developed for so-called diseases of lifestyle; a vaccine for smokers became hugely popular.

Most commercially available foods in Gauteng were produced by plants, animals, algae or single cellular organisms which had been genetically modified to optimise their nutritional value. It became routine practice to establish the nutritional status of an individual, using biotechnology-based tools. On the basis of these results, scientifically formulated and validated nutraceuticals would be prescribed to correct any deficiencies. Food was supplemented with, for example, proteins that were derived from biotechnological systems, such as single cell factories. This was done on a personalised basis. Protective coatings ensured that foods would reach their desired destination for optimal absorption following passage through the gastrointestinal tract that otherwise would have altered their molecular composition to be less favourable for delivery.

Biotechnology-enhanced diagnostic and screening technologies became commonplace. Microfluidic technologies incorporating biological materials allowed mass production of miniaturized, disposable, user-friendly diagnostic devices for home-based screening by the non-professional. Several parameters were often screened for in a single test. Diagnostic tests were performed in the doctor's rooms or at the patient's bedside based on the development of mobile, user-friendly diagnostic devices and easily accessible disposables.

Based on the knowledge that a family may have of their genetic predisposition to certain

diseases, it became accepted practice to perform pre-implantation diagnosis of embryos conceived *in vitro* which enabled the selection of embryos with low probabilities of the diseases in question. The screen evolved beyond monogenic disorders.

Progress in therapeutics was marked in Gauteng: biomarkers allowed the identification of sub-categories of diseases, each of which has a specific treatment regimen. Small molecule drugs, their design based on detailed molecular knowledge of disease mechanisms, were rendered safe and efficacious through the use of pharmacogenomics. Biologicals (e.g. proteins and antibodies) were likewise designed based on detailed molecular knowledge of disease mechanisms.

An ever-present threat to the province was the possibility of running out of water. Measures taken in the previous decade had helped significantly to reduce the demand for water, but as the population increased, so did the need for water. The GPG followed a double-pronged strategy to address this issue. First, they stimulated further reductions in water usage through a range of mechanisms, from variable water tariffs, to promoting the development and deployment of dry technologies to replace water based technologies (e.g. dry sanitation). Second, they lobbied the national Government to act to reduce the influx of people from other provinces, through for example awareness campaigns. These measures have certainly helped, but Gauteng is by no means out of the woods, and probably never will be. In fact, the effects of global climate change seem to be a reduction in precipitation in the areas that supply Gauteng with water.

By the end of the twenties the success of the knowledge society strategy appeared to be assured. There was a proliferation of small businesses in the province (400% increase since 2010), most of whom were KIBS-oriented. Only three townships in the province were now classified as having more than 40% of their inhabitants below the poverty line. A very significant indicator of success was the fact that, of the people in Gauteng's peri-urban areas who were entering the tertiary education system, 73% were doing so on the basis of informal qualifications rather than through qualifications gained within the formal education system, and the percentage was increasing.

Another significant development, seen by many but not all as positive, was a blurring in the roles of the provincial and local levels of government. Over the years there had been increasing collaboration between these two levels in the province, and the question as to why both levels were necessary or desirable became increasingly asked. There were those who felt threatened by the question, because of the perceived threat to their jobs, but consensus was building amongst the community organisations and the population as a whole that the province would be better served by having only one layer of government below the national level. By 2030 the local governments in Gauteng were actively lobbying the national Government for a change to be made in the Constitution to allow the option of Gauteng's provincial and local levels of government to be integrated. The GPG was not as enthusiastic on the matter, but were saying that the whole issue needed to be investigated. There was of course opposition to the principle from other provinces, but the arguments being offered by Johannesburg, Ekhuruleni and Tshwane for integration being necessary in the case of Gauteng were becoming increasingly difficult to counter.