

SCIENCE AND TECHNOLOGY IN TRANSFORMATION IN SOUTH AFRICA

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Introduction

Transformation might be explained by reference to an example from the field of metallurgy. When a piece of steel is subjected to a changing environment (quenched suddenly in water from red heat), it can undergo a characteristic process (a so-called 'martensitic' transformation), which can be modelled and which results in a changed structure (when viewed under a microscope) and corresponding changed mechanical properties (changed hardness and brittleness) which demonstrate changed behaviour.

There is a further feature that can often play a pivotal role in transformation, namely the presence of some catalyst. From our school days we might recall that a cooling liquid can be 'seeded' by a crystal of the solid form, to bring about rapid transformation (solidification, in this instance). Similarly, to extend our metallurgical example, small quantities of alloying elements can either accelerate or retard, even to the point of inhibition, the process of transformation described above. Although in this case not strictly correct, scientifically speaking, the use of the term 'catalysis' can, as we shall see, be usefully employed to describe this key role in transformation.

The metallurgical paradigm of transformation can be used to describe the organisational change that has occurred in the South African national research, development and implementation organisation, the CSIR, over the past five years.

In 1986 the CSIR embarked on a process of corporate restructuring which effected a dramatic, radical transformation of this, the largest R&D organisation in Africa.

The CSIR - the 'Current Reality' in 1986

With the benefit of hindsight we can say that the 'current reality' of the CSIR in 1986 more closely resembled a 'super university', rather than a market-oriented, contract R&D organisation operating along business lines.

The CSIR was established as a statutory research council in 1945. During the next forty years, the CSIR came to enjoy a high reputation for research excellence. At the same time, however, it grew into a large, relatively bureaucratic organisation with little understanding of the market forces that were increasingly beginning to dominate R&D trends world-wide. The terms that best describe the organisation prior to 1986 are phrases such as 'risk averse', 'lack of urgency', 'lack of communication', and 'bureaucratic'. At the same time, research excellence enjoyed a very high priority, as did pride in publication and individual accountability.

By 1986, the CSIR's original five institutes had increased to 27 structural entities.

The Changing Environment

Both within and outside the organisation, powerful new factors were at work.

Internal facilitators of change included:

- A gradual change in the composition of the CSIR Board to reflect much more closely the concerns and interests of industry;
- The personal style of the President of the organisation at that time, Dr C.F. Garbers. In the final years of his career at the CSIR, Dr Garbers was prepared to venture a great deal by embarking on a high-risk process of organisational change.
- Following the first top management review of the *Government's White Paper on an Industrial Development Strategy for South Africa*, the CSIR Board appointed a new Vice-President, Dr Brian Clark, with specific responsibility for technology transfer in the CSIR.
- A technology transfer task group was appointed in 1986 to evaluate how the CSIR would respond to the challenge of transferring technology. The task group found that, if we were to be successful, what was required was not merely some adaptation of existing ideas, but a fundamentally new approach. The CSIR therefore embarked on a strategic review of itself, starting after the first quarter of 1986, and resulting in the first explicit Corporate Strategy in October of that year.

External, local factors that were also making for a changed environment included:

- South Africa was starting to experience a period of enormous upheaval, and the potential for change was therefore high.
- In 1985 the previously mentioned *Government White Paper on an Industrial Development Strategy for South Africa* highlighted the need to achieve economic growth to meet the demands of a rapidly growing population. This White Paper made specific reference to the CSIR, stating that 'the CSIR in particular has at its disposal a comprehensive organisation for the transfer of technology to industry.' In view of this fact, the report notes, 'the Government has decided that the CSIR, in collaboration with the Department of Trade and Industry, should take the lead in devising an appropriate mechanism for the transfer of technology.'
- A new approach to science and technology policy in South Africa was taking shape, involving a move away from a centralised system of decision-making and control. As far as statutory councils were concerned, the trend was towards decentralising decision-making within a framework autonomy system, which meant that the boards of these statutory councils were being granted a great deal more responsibility and autonomy.

The international technological environment, too, was changing, and the CSIR could not afford to ignore global trends which were transforming the international science and technology arena (these trends are discussed in greater detail a little later).

The leadership of the CSIR at that time therefore had as its primary goal the processes which enabled the CSIR to plan for and adapt to the rapidly changing environment in which the organisation found itself. This was the catalytic role necessary to 'seed', lubricate, and indeed (in thermodynamic, or energy, terms) 'drive' the process of transformation. The decision to adopt an aggressive market-oriented strategy in order to become a force in boosting industrial growth was, therefore a visionary one; it implied that the organisation was prepared to change

radically, before circumstances beyond its control forced it to change or to suffer decline and stagnation.

A Changed Structure

Clearly, at the start of this process, we were in need of a radically different management style to lead the organisation through the disruptive period that lay ahead and to sustain the momentum of change over a number of years. Management, or leadership in the organisation, was to be the catalyst that would drive the process. The most essential component of the new approach we sought to implement was participative management within the framework of challenging performance targets with shared-responsibility teams striving to achieve those targets.

Managers had to become agents for the development of people and the organisation as a whole. Specific responsibilities would be delegated to them, but they would have joint responsibility for overall excellence in the organisation. We demanded further of them that they actively develop their subordinates' commitment and capabilities. This meant that they had to be repositioned, no longer as experts who had all the answers, but as facilitators and coaches who would help their subordinates to get the job done.

In this way, it became possible to create high levels of involvement without demanding centrality, and to distribute decision-making power to various levels of the organisation, thereby creating a strong sense of ownership and commitment. Another positive result of these participative approaches was that management as a discipline was held in very much higher regard throughout the organisation than before.

A Change in Behaviour

The results of any transformation or process of change can be measured in terms of changed organisational performance. As the results of a number of extensive internal and external surveys conducted in 1989 showed, both structure and performance had changed radically by that time.

The cultural descriptors used to describe the organisation in surveys in 1989 indicated a commitment to short, medium and long-term projects related to the needs of the marketplace; a high level of risk acceptance; directed research; a management-based culture; zero-based research budgets; high levels of pride in performance; a sense of urgency; performance as the pre-eminent requirement for recognition; a CSIR-wide horizon; high levels of group responsibility; and a business-like approach to R&D. These descriptors indicated that, to a large degree, we had achieved our original goals. That the process had been carried through to all levels was also borne out by the organisational performance in terms of financial parameters, productivity, and external benchmark surveys.

The financial performance can be summarised by saying that the level of external contract income grew significantly during exceptionally difficult economic times, while the per capita contract income experienced almost exponential growth during the same period. When we are compared with national research organisations

world-wide, it can be seen that our ratio of State funding to contract income places us second amongst the top contract income earners (just behind TNO, the Dutch national research organisation).

Productivity also improved, for at the same time as the staff complement declined from approximately 4 300 to approximately 3 600, contract income rose from approximately R28 million to close on R200 million.

South Africa in Transformation

The model of transformation described earlier can potentially be usefully applied to the much bigger macro-economic and socio-political scene in South Africa, with particular reference to the situation around the role of science and technology which we are addressing here.

A key requirement of any attempt to model the transformation of the South African science and technology/R&D situation is that it would have at its core the question of balance. It would have to recognise that in South Africa technology must meet both the needs of a growing population as well as the needs of the industries that will have to provide employment opportunities for that population. Hence the requirement to balance the needs of a largely disadvantaged society against the need to build a strong, export-oriented industrial sector. We shall return to this important point later.

South Africa - the Current Reality

The framework for debate is an economy in trouble. Our rate of unemployment, one of the most important indicators of the state of a country's economy, has grown from about 25% in 1980 to around 40% or even more today. Our real gross domestic product per capita has actually declined (from about R4 150 to just over R4 000 over the last decade). Our share of world exports fell from about 1.3% in 1980 to 0.6% in 1990.

This economic decline is taking place at the same time as the financial needs of our society in transition are growing rapidly. Not only do we have to tackle and redress the past injustices and inequalities of apartheid, but we also have to deal with the complexity of problems that confront all developing nations throughout the world.

Moving to the current situation of research and development in South Africa, the picture is equally discouraging. The developed nations of the world are today typically spending around 2.7% of their gross domestic product (GDP) on research and development. South Africa, in contrast, is currently spending about 0.7%, substantially less as a nation than many individual firms spend in the USA, West Germany, or Japan. And, while the developed countries have steadily been increasing the percentage of GDP which they spend on R&D, our percentage expenditure has been declining.

Another disturbing trend is the disproportionate involvement of government in R&D. In the developed nations of the world, for example America and Japan, some 65 to 70% of total R&D spending is by the private sector. In the developing nations,

on the other hand, the government is the major contributor to R&D spending: South Africa also falls into this category, with government contributing 73% of our country's total R&D expenditure (including substantial indirect funding via university subsidies and funding of government corporations).

In line with our declining investment in R&D, our technology 'balance of payments' also displays some alarming trends. Most of our exports, in technology terms, are low technology. In fact, for some time now, South Africa has been a net importer of both high and medium technology goods. Further, although we have all talked for years about the importance of 'value addition' for our export base, the reality shows the opposite: far from decreasing our dependence on the export of raw and processed materials, this has actually increased in percentage terms.

The current state of our education system is equally depressing. The South African economy must surely be placed on a sound footing, if historical inequalities of wealth are to be redressed in South Africa. However, our ability to create a strong economy depends to a large degree on the availability of an adequate supply of suitably skilled manpower. It is therefore highly disquieting to note that our black education system produces only one child with mathematics and science at matric exemption level for every 10 000 who enter the system.

Similarly, in 1988, for example, a total of 87,7% of graduates in science and engineering came from the white population group, compared with 12,3% from the other population groups combined. This is the principal reason for the current racially skewed composition of the population of practising scientists, engineers and technologists in South Africa. Owing to demographics alone, the demand for advanced and skilled manpower will increasingly have to be met out of the non-white population groups.

Instead of our S&T expenditure steadily increasing, however, the pragmatics of life in South Africa today results in government budget cuts and cuts in financial incentives for private sector technology. Instead of ensuring that scarce S&T manpower is retained and supplemented, there are retrenchments without due consideration being given to national long-term requirements; rationalisation of training facilities, instead of incentives for optimal utilisation of those facilities; inadequate incentives for S&T 'immigration'; inadequate manpower planning (with ensuing over- or undersupply in particular S&T fields), and minimal promotion of science and technology at schools.

Any improvement in attitudes towards technology and the effective management of the S&T system is hampered by, inter alia, internecine squabbles between the various parties concerned, and our inability as a 'community' to get our co-operative act together; minimal promotion of technology by public and private sector leaders; and investment preferences geared to financial rather than physical assets.

Co-operation and co-ordination between the various parties in order to use limited resources optimally are also impeded by a lack of national, general strategies for technology, industry and science. This leads to uncertainty as a result of ad hoc decision-making and increasing competition between organisations in the S&T field for short-term survival.

The current reality sketched above should be viewed against the background of a changing environment which is characterised by increasing competition, locally and abroad, from international competitors who are doing all they can to derive a competitive advantage from technology. It is this changing environment in the local and the international science and technology arena which is challenging current reality in South Africa and necessitating, on a national scale, a process of transformation.

However, it should be noted that not all is gloom and doom in the current South African science and technology scenario - there are certain factors at work which could well facilitate the kind of transformation under discussion. First of all, South Africa's infrastructure, and particularly its scientific and technological infrastructure, has been built up over decades and is unique in African terms. The CSIR, the largest RDI organisation in Africa, and a number of other organisations, too, are proof of this country's R&D strength. The excellence of our local R&D community is also a matter for the record. For example, in terms of the number of scientific articles published, we are significantly ahead of the newly industrialised countries (NICs), Taiwan, Hong Kong, South Korea, and Singapore. According to the Index of Scientific Power, developed by the Foundation for Research Development, which grades countries in terms of their scientific output, South Africa ranks 21st out of 154 nations. This achievement is less impressive, however, when we consider the fields in which we excel: ornithology, ecology, and medicine. We also currently spend more than 40% of our R&D funds on the social sciences; most western nations spend less than 12%.

The Catalytic Role of Technology in Transformation

All over the world, governments are revising their science and technology policies. Everywhere the realisation is steadily growing that, in the longer term, wealth is generated through the effective use of technology stemming from scientific endeavour. The wealth thus generated allows the needs of society to be met. This, in turn, means that society can afford to invest even more in research and development. This process produces an upward spiral of improvement in the quality of life of a nation. A recent CSIR comparative review of science and technology policies in 17 countries lends support to this view when it notes: 'The most successful economies - as exemplified by Japan and West Germany in the study - are those that use technology best across a broad spread of industries.' A good example of an under-developed country which used technology to move from Third- to First-World status is South Korea.

Determining 'Success Criteria' for a Change Process

When the change process is modelled, comparisons can be drawn. This, in turn, makes it possible to isolate key success factors that contribute to successful change and to draw up a strategy based on these factors. In the context of a South Africa in transformation in a changing environment, it is important to consider the experience of other countries and to determine success factors from a review of international

experience. Useful lessons can be learnt, for example, from the 'success stories' - the NICs, or newly industrialised Eastern countries, such as Japan, Singapore, Taiwan, and South Korea - and from the route they took to transform themselves in the course of a few decades from impoverished Third-World countries into highly productive, wealthy nations. The CSIR's comparative review of science and technology policies in 17 countries, referred to earlier, identified the following key success factors, among others, in the economic performance of the newly industrialised countries as well as countries such as Sweden and West Germany:

- *Technology policy as an instrument of economic policy.* Policy makers need to see technology policy as a key enabling instrument of economic policy.
- *Long-term, flexible government strategy.* Government needs to be willing to formulate and to commit to sound economic and technological development strategies.
- *The role of government.* Government plays a crucial role in exercising overall leadership, in creating a macroeconomic and regulatory framework conducive to technological innovation, and in effecting the appropriate volume and quality of investment in education and training.
- *The need to distinguish between science and technology.* Competence in technology may not be dependent on, or even related to, competence in science. Indeed it is possible in the short term for a country to be competent in utilising and adapting technology developed elsewhere without itself having a strong science base.
- *The strategic capacity to manage technology effectively,* at the level of the overall economy as well as that of the individual firm.
- *An efficiently functioning national innovation system,* properly connected with outside systems and in which the science, technology, market and finance 'poles' interact readily with one another.
- *Market responsiveness and the role of large companies.* Ideally, the strategic role of government should be reinforced by a strong business sector responding both to government stimulation and to international market demand. The private sector should be primarily responsible for adopting and upgrading technology.
- *Government-business rapport and collaboration.* Close ties between the public and private sectors are essential, with both sectors focusing on shared goals and values. Private sector involvement in the policy process should take place at both strategic and operational levels.
- *Investment in development of human resources.* Heavy investment in general education and in vocational training is a characteristic shared by all the 'success story' countries. They recognise that the skills of their people are the fundamental resource, and that literacy and numeracy are prerequisites for these skills to be developed. There is a vigorous commitment to education and training as a means of personal and career development for the individual, and as the key ingredient in long-term development of the whole economy. Within this overall commitment there is a strong emphasis on technological and other applied skills at the tertiary educational level. This emphasis is strongly complemented by investment in more narrowly-based technical skills at below-tertiary levels.

- *Investment in physical infrastructure.* Investment in physical infrastructure has played a vital part in the development of the NICs.

When one considers international experience, it is clear that one cannot strive for the perfect policy, and that the emphasis should in fact fall on an evolutionary policy development which is at all times directed at rapidly achieving success in those areas which are important at that specific stage. For example, Japan, Korea, Singapore and Taiwan, followed a roughly similar evolutionary path based on the acquisition and adaptation of foreign technology. Japan is typical of this process. Following the Second World War, the Japanese government followed a strategy involving the acquisition, initially from abroad, of technologies with significant long-term world market potential, and of progressively adapting and improving them to meet new market conditions. Acquisition and modest adaptation of foreign technology in these countries are followed by the development of their own technological capabilities which stimulates investment in the sciences that underpin them.

Transforming South Africa will undoubtedly be a learning experience, just as much as the restructuring of the CSIR was a learning experience for all involved. In addition, our model of successful transformation clearly shows that we do need a science and technology strategy, based on the key success factors, as identified by a review of international experience, and linked closely with South Africa's industrial strategy.

Determining a Strategy for Transformation

In response to the challenge posed by a changing environment, it is necessary to draw up a strategy for a process of change. This process should result in a changed organisational structure and changed behaviour, which will make it possible for the organisation or country concerned to cope in the new environment.

The success factors discussed in the previous section clearly play a key role in any science and technology strategy. At the same time, they have to be adapted to our specific circumstances. In South Africa, this means that we should strike the correct balance in our R&D endeavours. One of the questions we need to ask ourselves in this regard is: how much money, if any, should we spend on the so-called 'leading-edge' technologies? These are hi-tech interdisciplinary technologies which have become the driving force in technological advances in the industrialised nations, and they include microelectronics, materials technology, biotechnology, information technology, and advanced production technology. Although research in these fields lends prestige to a country's R&D efforts, such research is often prohibitively expensive for a country to undertake on its own, while also sometimes being inappropriate to the specific needs of a country, especially a developing country. On the other hand, to fall behind in some of these fields would undermine our technological base in other vital fields. For example, information technology is a crucial, interdisciplinary technology, and for us to fall behind developments in this field could jeopardise our efforts in a dozen other areas. The ability to make full use of, and exchange information on these technologies is therefore critical.

Experience has shown that the technology aimed specifically at addressing the

needs of the community can be either high, medium or low technology - the nature of the technological solution depends on the nature of the problem being addressed. A mistake which has often been made in Africa, especially by outside development agencies, is to assume that the more complex the technology used to solve a problem, the better the solution. When breakdowns then shut down expensive projects, it is often found that the local community has not been properly involved, or given the necessary training or even equipment to keep the technology operational. It is now widely recognised that technology aimed at the needs of developing communities must be planned in consultation with the community; that it must be aimed at meeting specific needs; that it must involve the community in all stages, from the needs determination stage to the commissioning, operational and maintenance phases; and that such technology should be affordable, feasible, and appropriate to the project.

Some Aspects of 'Structure'

While not wishing to preempt the old adage 'structure follows strategy', it would be instructive at this stage to consider the role of national research councils as enablers of industrial and economic development. They can make a vital contribution towards facilitating change and promoting a balanced spectrum of R&D, appropriate to the country's needs.

National research councils are a world-wide phenomenon. They are found in industrialised countries and in developing countries. They have different forms and very different purposes in each country, but their usefulness as a mechanism of establishing a critical mass of scientists and technologists to achieve specific purposes has been proved many times. Special mention should be made in this regard of the CSIR, which is South Africa's foremost scientific and technological asset. The CSIR is the biggest research and development organisation in Africa. More than 1 500 CSIR scientists and researchers and their support staff in many parts of South Africa undertake broadly-based, market-driven research and development to meet the needs of the South African public and private sector and to improve the quality of life of all South Africans.

Given the fact that more than 99% of the world's development of technology and R&D is done outside the RSA, organisations such as the CSIR serve a vital role as a 'funnel and bridge' - a funnel through which international scientific and technological advances are channelled into South Africa from abroad; and a technology bridge for the transfer of scientific and technological advances to South Africa, the Southern African region and, ultimately, to Africa as a whole. The CSIR is part of the global scientific and technological development community, and its experts are at the forefront of research and implementation across a broad range of technologies. The blend of the organisation's Africa expertise and the financial and technological capability of the First World constitutes a valuable mechanism for sustained development in collaboration with African countries.

The existing CSIR infrastructure is therefore an important enabling mechanism for the ongoing development of South Africa. It might not be perfect, but in the African context it is unique and a major potential force for change. In terms of our

paradigm, the role of statutory research councils such as the CSIR is to drive technology as the catalyst for implementing the transformation of our current reality. There is a need for R&D aimed both at enhancing competitiveness within the private sector and at improving the quality of life in our developing communities. These aims can best be served by mission-oriented, focused research, and a market-oriented approach based on a balanced mix of short-, medium- and long-term programmes.

Transforming South Africa - Time is Running Out

South Africa currently finds itself preoccupied with the process of constitutional negotiation. An important lesson from the world community is that no country has been able to democratise its political structures at a time of negative economic growth. The goal of sustainable economic growth is, therefore, vital to long-term success in the socio-political arena.

Like the piece of steel referred to in our introduction, our strategy and policies relating to science and technology need to undergo a transformation. The challenge facing us is to incorporate lessons learnt from international experience into a model for structural change which is appropriate to our own very specific circumstances. In the face of technology-driven global competition, a solid technological base must surely be critical for our longer-term survival. At the same time it is important to address urgently the needs of South Africa's rural and developing communities, as well as those of the informal sector and the small business sector, where technology can and must play a special role.

It is precisely because we have so little time that we cannot afford to repeat the mistakes other countries have made. International experience in this field has been meticulously recorded and evaluated. The lessons are there, if only we are prepared to heed them; the criteria for success are there, if only we care to consider them; the road has been prepared for us, if only we would take it.

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