FORESIGHT MANUFACTURING REPORT

Foreword

The Manufacturing and Materials has highlighted some of the most important issues that will be crucial for the success of the manufacturing sector into the new millennium. Manufacturing as the engine of economic growth of South Africa has to be in a healthy state and thus its competitiveness in a globalized world becomes crucial.

Since our manufacturing industry has been introduced to this competitive environment, restructuring within industries has necessitated a long-term vision to be developed.

The National Research and Technology Foresight under the auspices of DACTS has accorded our industry this opportunity. The members of the Manufacturing and Materials Sector Working Group have made strong recommendations which if implemented as speedily as possible can make our industry to be on its way of taking its competitors head-on.

The creation of a highly innovative industry and the enabling environment for the success of the South African industry has been noted as one of the important areas of focus. Product and process innovation coupled with a strong market focus are one of the ingredients of success that were noted. Therefore, NRTF has contributed to the fusion of technology with business processes which I personally take pride in. Development of a highly skilled work force and the training processes and methods were also found to be important for the Manufacturing sector to reach its competitiveness status.

I would therefore like to take this opportunity of thanking the working group members who stood by the process to its completion. The Foresight process wouldn't have been completed without your insight and dedication to this important national exercise. Furthermore, I would like to extend my gratitude to those organizations and individuals that have dedicated their most valuable time to the success and completion of this process.

This gives me pleasure in acknowledging the excellent work that you put into this even though more work still lie ahead of implementing all these recommendation. Your response when called upon again would be highly appreciated.

I also hope that in our next rounds of Foresight we would improve on what we have done and contribute to the success of our industry.

Mr. Peter Watt

Chairman: Manufacturing and Materials

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Abbreviations and Acronyms

DACST.................. Department of Arts, Culture, Science and Technology
DBSA.. Development Bank of Southern Africa
DEAT.......................... Department of Environmental Affairs and Tourism
DTI.. Department of Trade and Industry
EIU .... The Economist Intelligence Unit
FRD .... Foundation for Research Development
HR...Human resources
ICT ....Information and Communications Technology
IPR .... Intellectual Property Rights
MCST .... Ministerial Committee on Science and Technology
NGO ....Non-governmental Organisation
NRTF ....National Research and Technology Foresight
NRTA ....National Research and Technology Audit
NSI ....National System of Innovation
OECD ....Organisation of Economic Cooperation and Development
R&D .... Research and Development
R&T..Research and Technology
SACOB..South African Chamber of Business
SADC................................... Southern African Development Community
SATOUR .... Tourism South Africa
S&T ....Science and Technology
STEEP ....Social, Technological, Environmental, Economic and Political
SWOT ....Strengths, Weaknesses, Opportunities and Threats
THRIP........... Technology and Human Resources for Industry Programme
SMME .... Small, Medium and Micro-enterprises
WTO..World Tourism Organisation
WTTC World Travel and Tourism Council

Executive Summary

A Working Group drawn from members of industry, academia, government, para statals and the NGO sector was convened by the Department of Arts, Culture, Science and Technology to examine the impact of likely driving forces over the next twenty years on the Manufacturing and Materials sectors and their markets. The initiative aimed to identify key technologies and how these technologies were likely to impact the sectors contribution to quality of life and wealth creation for South Africa and it's broad population.

The South African Manufacturing and Materials sectors are at a crossroads given the increased liberalization of the local economy and the re-entry of the country into the global arena over the last five years. A decade and a half of isolation has left these sectors more inwardly focused than their international counter parts and has resulted in many instances in a lack of competitiveness. Technology development, assimilation and application will be the crucial determining factors of how, and on what terms, the local industry integrates into the international market.

The working group has made six sets of recommendations regarding the leveraging up and positioning of the Manufacturing and Materials sectors. Many of these recommendations refer to 'softer issues' such as: human resource development and legislative and regulatory frameworks which will allow these sectors to position themselves in a market from which they have been absent for some time. The highlighting of such issues is consistent with a country under going the level of economic and political transformation, which South Africa is experiencing.

On the technological front, recommendations are made concerning the need to increase the technological capacity of the work force, and to achieve such an upgrade of skills through specialization and the use of ICT in it's various forms.

Recommendations are also made concerning the key technologies, which will need to be developed within the sectors in order to increase their competitiveness. These include issues of automation, utilizing new and smart processes at all points along the value chain, developing technologies which reduce time to market, as well as the use of smart materials and materials which are more environmentally friendly and which are renewable.

The technology and business process imperatives are addressed and highly recommended.

Chapter 1

1.1 Introduction to the Foresight Process

In an era characterised by increasingly rapid changes in technology, global economic relations and socio-political dynamism, a country's ability to keep pace with such changes plays an increasingly important role in the nation's ability to prosper, grow and provide for its citizenry.

New technologies are expected to have a profound social and economic impact in future. However, the increasingly capital-intensive nature of science and technology as well as the reality of finite resources has led to a recognition that no country can afford to support top-quality research and development in isolation of broader policy and national goals. It is also realised that the interaction between different stakeholders in a national innovation system[1] is more complex than described by traditional 'linear models,' and involves feedback mechanisms, with research needs arising at many points in the process of development and growth.

Foresight is a systematic process that seeks to understand the long term. It assumes that there are many possible future scenarios and that the shape of the future we inherit depends on the decisions taken today. An important aspect of foresight is the use of qualitative as well as quantitative methods to set priorities and agree on actions. This process involves widespread consultation among all relevant stakeholders. This latter feature is perhaps what most distinguishes foresight from forecasting, which tends to be more deterministic and technical in approach.

The overall aim of technology foresight is to help prepare for the future. Taking specific sectors or themes, foresight seeks to align supply and likely future demand. It does this by bringing together users andother stakeholders with researchers and funders to consider the future of their sector over a 10- to 20-year period.

In South Africa, the Foresight project is being launched against a reality of declining international competitiveness, relatively low levels of R&D investment and a need to transform our national technological goals. The project has been initiated by the Department of Arts, Culture, Science and Technology as part of its development of a common vision for the role of science and technology in South Africa through a coherent National System of Innovation. The project will build on and complement the Industrial Cluster Initiative[2] of the Department of Trade and Industry. The outcomes of the Foresight project, along with other policy initiatives, will contribute to new directions for science and a commitment to work cooperatively with the private sector and civil social needs of the country consistent with the national growth and development strategy.

1.1.1 Features of 'foresight'

Foresight can best be seen as one of many tools that may be used by government or industry to help influence strategic decision making and thus to influence the future. Foresight brings focused thinking to bear upon the role of science and technology in national development through what have been the six Cs:

- communication by interaction with stakeholders
- concentration on the longer term
- coordination and partnership
- consensus
- comprehension of the factors of change
- commitment to implementation.

As such, the Foresight process and methodology are relationship-intensive and bring together government departments, industry, science councils, higher education, organised labour, professional organisations and other stakeholders who previously related to each other in a highly fragmented manner, which resulted in sub-optimal resource allocation and outcomes.

1.1.2 The international perspective

South Africa is among the first of the newly industrialised countries to conduct a foresight study and has therefore learned from international experience while making necessary adaptations to make the process effective for the country's unique position. It may be of interest to look briefly at the experiences of several other countries.

1.1.2.1 Japan[1]

Japan is considered the 'home' of foresight. Since 1971, the country has made widespread use of Delphi surveys to ask the science and technology community about future technological trends. The surveys are conducted every five years by the National Institute of Science and Technology Policy. In Japan, the foresight process has no formal implementation phase but is rather used as background information for decisions taken by agencies, departments and institutions based on their own priorities for government-funded R&D projects.

1.1.2.2 Netherlands[2]

In the Netherlands, a form of technology foresight has been integrated into technology policy by the Ministry of Economic Affairs since 1989. These foresight studies aim to outline potential applications of new or existing technologies which can be expected to be widely applied in the Netherlands within five to ten years. The main objectives are to generate information for strategic technology policy planning, to provide small and medium-sized enterprises with information on recent technological developments and to stimulate innovation through the development of networks.

The Dutch approach differs from that taken in other countries in the extent of consultation. For example, they have wide consultation in developing a consensus and commitment on which technologies to pursue. There is no guarantee of new money so the emphasis at implementation stage is on the redistribution of existing resources. In addition, the Ministry of Education and Science is carrying out its own foresight activities. The findings influence the four-yearly Strategic Policy Document produced by the Department in which priorities for Dutch scientific research are indicated. The aim is to assist in priority setting both in and between different fields of research.

1.1.2.3 Korea[3]

Korea in 1992 initiated a foresight exercise as part of a newly launched national R&D programme, the HAN (highly advance nation) project. The aim of the HAN project was to improve the competitiveness of domestic industries by increasing indigenous S&T capability, thereby reducing the dependence of Korea's industries on foreign technology. The Korean government intended the outcome of the exercise to translate directly into the establishment of priorities and the funding of targeted areas. The conduct of foresight represented a shift in government thinking, which now took the position that the direction of science and technology should be determined less by individual research interest and more by national goals, i.e. a shift from bottom-up to top-down.

The HAN project involved government scientists and technologists, independent research organisations, firms and universities. The Foresight procedure involved monitoring emerging technologies and identifying problems, setting priorities and selecting key technologies, which were then grouped into 60 areas. A set of foresight committees was then established to monitor each technology, discuss possible impacts, and reach consensus in relation to national goals. The process has been described and 'planning as learning by interacting'. The final outcome was a list of five product-oriented technologies and six fundamental technologies.

1.1.2.4 The United States[4]

The United States has not carried out foresight exercises as such, but has concentrated instead on drafting lists of critical technologies. In 1990, the US established the National Critical Technologies panel, which was charged with identifying and reporting on up to 30 national critical technologies considered essential for the long-term national security and economic prosperity of the US. This panel produces biennial reports, the first of which was published in 1991. The US Congress also set up a Critical Technologies Institute. Its remit was to explore and develop proposals to advance critical technologies and to develop a strategy for federally funded R&D in each critical technology.

1.1.3 The South African Foresight Mission

The mission statement of the South African Foresight endeavour is:

'To promote technological innovation and deployment by identifying opportunities for economic and social development through a national research and technology foresight project'.

The success of any such broadly defined project depends on the establishment of clear objectives at the outset, as seen in the country examples above. For the South African project, these objectives were divided into three categories of objectives: process, output and implementation and outcome.

Process objectives:

- To identify those technologies and latent market opportunities that are most likely to generate benefits for South Africa;
- To develop consensus on future priorities amongst the different stakeholders in selected sectors (industrial, socio-economic or service);
- To coordinate the research effort between different players within selected sectors; and
- To reach agreement on those actions that are needed in different sectors to take full advantage of existing and future technologies.

Output and Implementation objectives:

- To contribute to broad policy guidelines in S&T consistent with the National Strategic Vision;
- To develop a consensus on priority areas between different stakeholders in S&T;
- To identify possible funding priorities for publicly funded research;
- To build capacity in foresight methodologies;
- To gather intelligence, particularly for industry, on future opportunities;
- To encourage greater R&D investment from industry;
- To improve communication between public and private sector in S&T;
- To advise on the implications of the findings for skills development; and
- To focus capacity development in the tertiary sector.

Outcome objectives:

- Alignment amongst the major role players in the National System of Innovation; and

- Institutionalisation of foresight capacity in government departments and industry

1.1.4 The Foresight Plan

The Foresight Project was conducted over an 18-month period and was designed to be sectorally based while allowing for the capture of cross-cutting issues and themes.

1.1.4.1 Three-phase approach

The project took place in the following three phases:

Phase I, the pre-Foresight phase, was essentially the design stage and included the establishment of detailed objectives within the context of national policy initiatives, the establishment of internal and external liaison structures, alignment with other initiatives, consultation with the community and an analysis of local and foreign foresight studies.

Phase II, the main Foresight phase, provided the pith of the process and involved the identification of key issues (STEEP = Social, Technological, Environmental, Economic and Political) in each sector, an analysis of the likely impact of these on the development of sector, the implications of these developments for markets, products and processes, an analysis of the technological developments underpinning new products and processes, and finally an assessment of the actions needed to realise new developments in each sector.

Phase III, the post-Foresight phase, is envisaged to include the dissemination of Foresight findings, the development of implementation plans based on findings, the monitoring and updating of the Foresight output, and the institutionalisation of foresighting capacity in government and industry.

The Foresight project has been overseen by a high-level Board appointed by the Minister on the basis of public nominations and extensive consultation. Theday-to-day work of the project has been carried out by a project management team in collaboration with sector working groups. The responsibilities and members of the Board are listed in Appendix 1.

1.1.4.2 Foresight sector selection

One of the crucial activities of the pre-Foresight phase was the sector selection and definition. As sectors would be the core operational component of the entire Foresight process, careful attention was given to the process and it was conducted in an inclusive and transparent manner with a strong focus on participation and empowerment so as to ensure a high level of 'buy-in' and ownership of the process by the various stakeholders. In total, delegates from 21 academic and research institutions, 34 businesses or industries, 10 national government departments and policy NGOs and many provincial government departments as well as all eight major science councils participated in this extensive national and provincial workshop process.

The composite outputs of the workshops were treated with a preliminary analysis and re-bundling by the Project Management Team to yield a list of 16 sectors, which were presented to the Advisory Board and circulated to all the workshop participants for comment. Finally, 12 sectors were identified to be taken forward into Phase II of the Foresight planning process.

1.2 Sector Landscape

The Manufacturing and Materials Sector's vision for the future will consider the most innovative ways of using product and process technologies and proper business processes to increase the competitiveness of these sectors. Within this landscape, two issues are highlighted. First would be the need to consider both 'hard' and 'soft' issues pertaining to the sectors. Second is interdependency along the value chain rather than subsectoral, discrete analysis.

Three major areas of product, process and support technologies were initially used as the focus points for the sector process. They are:

- Major trends impacting on work and lifestyles in the future
- Value chain management
- Trends in product and process development

1.2.1 Major trends in work and lifestyle

Five major trends were identified as possible factors that will shape future work patterns as well as lifestyle patterns. First, it is anticipated that service industries and service within product industries will become increasingly important. Second, it is accepted that brainpower or knowledge capacity will become the discerning factor in future growth and development. This moves away from traditional thinking, which gauges a nation's capacity to grow on the basis of the volume of land, labour and capital it has at its disposal. Third, it is accepted that the industrial age is coming to a close and that the future lies in the dawning age of information. Fourth, it is accepted that individual worker contributions to organisations will become increasingly important, implying that the perception of the 'worker' will need to evolve, as will the importance of stakeholder activity and decision making. Finally, it is believed that the days of the mega-organisation will wane and that the dynamism of small business will figure prominently in the new Information Age.

1.2.2 Value chain management

A second major influence on the future of the materials and manufacturing sectors will be that of value chain management. Specifically, it is believed that the practice of lean thinking, which will become the de facto standard, will require strong leadership from within the value chain to thin down operations, drive out waste, cut prices, increase quality and raiseservice standards. To achieve this it is believed that increased dependency on IT and human resource development will continue and grow. Finally, it is believed that output will be reconfigured to focus on speedy adoption and changeover in technology, as well as decreasing work in progress and long production runs.

1.2.3 Trends in product and process development

Three overarching trends were viewed as being particularly pertinent to the materials and manufacturing sector in the next 20 years. First, there will be increased migration to and adoption of new product-development tools such as CAD, CAM, rapid retooling methods and virtual prototyping, offices and the like. Secondly, flexibility will become increasingly important in all spheres. Thirdly, the recycling of limited natural resources and life-cycle analysis will become increasingly prominent issues in both product and process development and implementation.

1.3 Term of Reference

The Manufacturing and Materials Sector Working Group was charged with the following terms of reference:

I. Agree on proposed sector focus
II. Analyse the current status of the sector
III. Identify future research and technology challenges and market opportunities over the next 10-20 years
IV. Make recommendations on the identified crosscutting issues (areas)
V. Compile a prioritised list of research and technology topics for the sector
VI. Make recommendations on implementation strategies
VII. Compile the Foresight sector report
VIII. Help to identify research and technology themes towards designing of appropriate research programmes
IX. Communication of processes and findings.

1.4 Workshops

A total of nine workshops were conducted, each characterised by a spirit of openness, debate and collaboration. Initial workshops focused on understanding the process and methodology of Foresight. These were followed by workshops focused on accumulating substantive input for the SWOT[1] and STEEP[2] studies in the context of the four scenarios considered by the study. The third series of workshops focused on the development and fine-tuning of the Delphi survey; with the final workshops aimed at interpreting the Delphi responses and collating these responses with earlier work so as to produce a final list of recommendations.

1.5 The Co-nomination Process[3]

Selection of members of each Sector Working Group was done via a process of co-nomination in which a survey questionnaire was sent out to a variety of stakeholders and the broad community, requesting them to identify particular individuals who could participate in the working groups. This process was completed and individuals were finally appointed by DACST in consultation with the Advisory Board and the Project Management Team. A list of the Manufacturing and Materials Sector Working Group is supplied in Appendix 2.

1.6 Participants in the Stakeholder Consultation Process

The broad consultation process used for sector selection as well as co-nomination included consultations with, inter alia, 21 academic and research institutions, 34 businesses and business associations, 10 national government departments, various NGOs, several provincial departments of economic affairs, all eight of the national Research Councils and various umbrella civic organisations, trade unions and youth organisations.

Chapter 2: Benchmarking[1]

2.1 Introduction

This chapter seeks to place the South African manufacturing and materials sector[2] in perspective relative to other international world players. This 'benchmarking' will cover the nation's performance and positioning both in terms of the supply and demand of materials and manufactured goods and in terms of the nation's performance and positioning with regard to research and development in these sectors.

In a world of increasingly fewer economic boundaries and borders, where capital and technology are more mobile than at any time in the history of man, benchmarking a nation relative to the world is no longer an academic exercise performed in the ivory towers of educational institutions, but a vitally necessary tool with which governments and private sector companies can position themselves in the global arena.

2.2 Global Status of Manufacturing

Manufacturing in the new millennium will differ most notably from the preceding one in that manufacturing is now a global activity. This transformation results from three key factors, namely rapid trade liberalisation; technological developments that reduce transport and communications costs while simultaneously increasing efficiency and effectiveness, and finally, reductions in the costs of transactions between countries, the development of cost-reducing institutions such as the multinational firm, and movement to more compatible commercial laws and standards.

This new global environment within which manufacturing occurs has resulted, at a macro-economic level, in over-capacity, consistent and continued falling real prices for manufactured products, and the rapid transfer of technology and production to low-cost countries. Such company production and investment decisions are now based on whether a host country offers internationally competitive production costs, what the size and access of the host country market is, and the strength of the research and development and engineering skills base in a country. Developing, expanding, retaining or attracting a manufacturing base is now less of a national decision, but rather an international decision where marketing and the development of free-trade blocs become increasingly important.

Manufacturing is moving into an era of tri-polar global competition, with the broad trading blocs of Asia, Europe and North America, changing the playing field for all other manufacturing competitors. These blocs have revolutionised everything from customer service to the definition of products, markets and value. Consumers of manufactured goods now demand product reliability, conformance quality, after-sales service, broad line, on-time delivery, product support, fast delivery, product durability, mix flexibility, performance quality, product customisation, volume flexibility, design flexibility, low price, and new product speed.

These deliverables have required successful manufacturers to adopt a process of continuous improvement, massive investment in new manufacturing technologies and innovations and information systems, particularly the integration of information systems across functions. Another new development is the rise of inter-organisational initiatives, such as customer partnerships and supplier partnerships. Increased investment in cross-functional systems, combined with greater emphasis on external partnerships, indicates that the necessary focus of continuous improvement is no longer sufficient in the international market. Manufacturers are now also required to embrace a broader, more complex paradigm involving themselves, their suppliers, and their customers as partners in their endeavours.

The demands on a manufacturer to be internationally competitive are more onerous now than at any other time during the Industrial Age. Despite this, it is interesting to note the role of developing nations in the globalisation of manufacturing. Developing countries, which traditionally remained on the periphery of the industrialised countries, are now finding themselves strongly integrated into the system, and are rapidly becoming a major force in world trade in manufactured goods. These countries' share of world manufacturing exports increased from less than 10% in 1970 to 35% in 1996. Also, developing countries' manufacturing value addition has increased steadily to 17,4% of world MVA. Developed countries' MVA continues to decline as they continue to outsource their manufacturing base while developing their local service and financial sectors.

2.3 South African Manufacturing Status

The manufacturing sector contributes 24% (1998) to the country's Gross Domestic Product (GDP) and employs 19% of the nation's workforce. As such, the manufacturing sector is highly relevant to the future growth prospects of the country. Despite its importance, the manufacturing sector in South Africa is far from healthy. GDFI has fallen from an average of 27% in the 1970s to 17% in the nineties. Our political and economic isolation and our previous policies of protectionism and import substitution have resulted in extremely low levels of specialisation and hence low competitiveness. Despite the increasing capture of market share by developing countries, South Africa's share of total manufacturing exports of developing countries decreased from almost

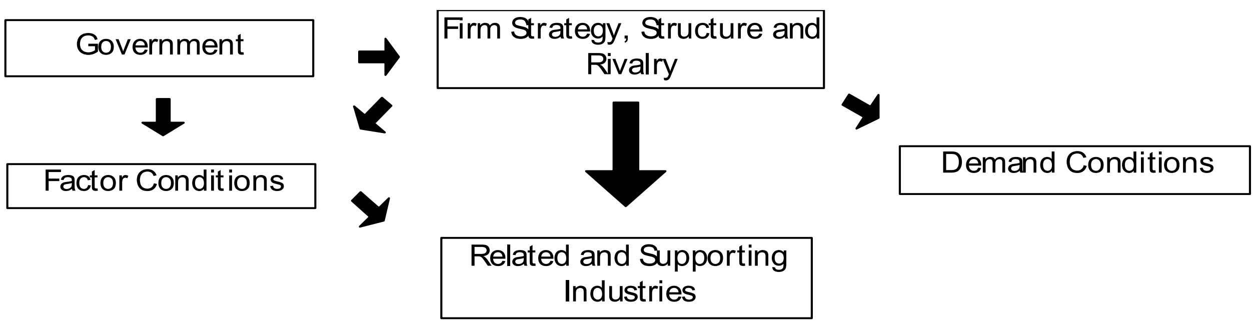
12% in 1975 to 1,5% in 1993, showing that our manufacturing sector is not only failing to keep pace with change but is in fact lagging behind and losing market share. Many of the reasons for the country's poor manufacturing performance are highlighted in the diagram that follows.

These findings are confirmed by those of the World Competitiveness Report (IMD: 1997), which ranked South Africa 44th out of 46 on the competitiveness scoreboard in 1996, and 16th out of 18 on the non-OECD scoreboard. South Africa was ranked 45th out of 46 with regard to investment attractiveness and 45th out of 46 on competitive aggressiveness. In terms of the strength of the domestic economy South Africa was rated 42nd out of 46.

In terms of international benchmarking, South African manufacturing is not internationally competitive for the following reasons:

- The country fails to pass on inherent advantages in raw materials to local downstream manufacturers because of dual pricing and import parity pricing policies.
- Raw-material production is suboptimal owing to outdated technology and short production runs aimed at broad product ranges.
- In the past, manufacturers relied on South Africa's relatively cheap labour to gain a conversion cost advantage over higher wage countries. In many instances, South Africa no longer enjoys this advantage. In addition, our higher-wage competitors are increasingly using technology to reduce the direct labour cost of manufactured goods. At the same time, South Africa's direct labour cost per unit significantly exceeds that of low-wage countries.

Factors implicated in poor competitiveness in South African manufacturing (source: IDC Studies, 1997)



- Historical policies promoted inward focus and concentration of power.
- Upgrading of basic factors has been skewed.
- High taxes reduced private spending and customer sophistication.
- Unsophisticated customer.

- Strong basic factors (minerals, climate, and pool of relatively low-cost labour). However, not efficiently utilised.
- Limited upgrading and specialisation of basic factors occur.
- Geographical distance from major markets and historical inland economic development has resulted in high transport costs.
- Domestic market focus leads to lowest-cost strategies and limited factor upgrading and specialisation.
- Dominated by conglomerates.
- Low levels of domestic rivalry
- Limited exposure to global competition.
- Compete on basic factors (i.e. low energy cost, natural resources and relatively cheap labour).
- Adversarial management-labour relations.
- Important supporting industries are poorly developed (i.e. machinery, training and education).
- Suppliers often pass on price, service and quality disadvantages.
- Conflicting relationships, rather than 'mutual destiny', are common in South African cluster.
- Significant numbers of domestic customers are unsophisticated and price sensitive.
- Demand lags, rather than leads, international demand in most products.
- Low economic growth contributed to slow growth in domestic purchasing power.
- South Africa has insufficient upgrading and poor specialisation of factors of production. Outdated machinery and equipment on the factory floor have been mirrored by outdated management approaches and the absence of proper work organisation, total quality management, materials handling, and just-in-time production, and low spending on training and R&D has further compounded low productivity and a lack of competitiveness.
- The overheads and marketing costs of South African manufacturers significantly exceed those of their international competitors. Factors that contribute to these high costs include elaborate overhead structures, even in companies that produce low volumes, large indirect staff complements that manage and administer overly complex product ranges, and large customer and supplier accounts.
- The domestic market is small and export remains focused on primary goods. Manufactured goods account for only 25% of South Africa's exports, with 40% of these destined for SADC markets and the remainder focused on our traditional European trading partners.

While the picture may appear bleak, South Africa's manufacturing outlook has great potential. Survival and growth strategies need to include —

- a focus on niche markets (both domestic and for export);
- a focus on core competencies;
- strategic and technological alliances with overseas partners;

- steps to improve productivity and work organisation;
- competing on service, product support, product customisation, fast delivery and other aspects not directly related to price;
- exploiting comparative advantages in terms of raw materials and electricity pricing; and
- lastly and most importantly, increasing, focused investment in R&D and product and process innovation.

2.3 Research and Technological Benchmarking

Before formally benchmarking South Africa's R&D and technology base against that of its world competitors, it is interesting to consider the trends and areas of focus currently on the international technology agenda with regard to manufacturing in the next millennium. These technologies are encapsulated in the table below and are driven by the market demand described in previous sections of this chapter.

The satisfaction of demand is a complex integration of elements (including products, processes, material inputs, manufacturing systems, and the organisation), each of which has its own systematic framework. Relevant to this study is technological innovation within the production domain and generating 'new or improved' elements that meet the needs of consumers and society. From this, a range of issues can be derived. These issues call on R&D endeavours to supply missing knowledge and means of exploiting opportunities that may arise. International competitiveness in manufacturing in South Africa will be influenced by our sectors' ability to embrace these technologies, either by importing them or by developing them locally. Each of these technology response items will be dealt with.

2.3.1 New or improved products

Growing discrimination in the tastes and desires of consumers, as well as the marketing efforts of firms, which introduce new possibilities, drives the production of new or improved products. Sustainable consumption patterns are forcing producers to look at alternative design and manufacturing methods. These issues are encompassed within the following three broad areas of product engineering:

Global demands	Response	Technology Response	
		Demand Features	Technology Issues
High-variety/low-volume products Sustainability	New or improved products	Size Function Materials Customisation/ Standardisation	Miniaturisation Multifunction Recyclability Electronic product data interchange
	New or improved processes	Size, Quality Quality, Variety Function	New transformation processes Waste minimisation Combining materials
	New or improved materials inputs	Size, Function Sustainability Function	New materials Waste minimisation Combining materials
	New manufacturing	Dynamic continuous change	Integrated prod./ process.

- Miniaturisation: Miniaturisation is a response to the need to concentrate functionality in confined spaces and reduce material requirements. Major areas of application are advanced maintenance technologies for power plants, micro-factory technologies, and micro-machine technologies for power plants.
- Multifunction products: Multifunctionality offers a solution to demand while keeping material consumption down. Principal areas of application include robotics, control systems and medical devices.
- Re-use of components and recyclability: Issues of environmental protection and sustainability receive a great deal of attention in current thinking. Minimum degradability of materials used, well-thought-out materials and product design, and waste minimisation are the key requirements for re-usability.
- Electronic product data exchange: The emergence of specialist manufacturers of components or families of components requires effective integration of these components into a final product. A common architecture of product data will be required to respond fast to suppliers' requirements. This requires integrated and standardised product design and sophisticated design and database systems.

2.3.2 New or improved processes

The application of emerging scientific developments as well as already established technologies are the driving forces for new or improved processes. Increased integration of product design with process design is a key issue. The areas of focus are the following:

- New transformation processes: The rationale for new transformation processes is the need for precision in forming and finishing materials. In particular, developments in ceramic materials have demanded new finishing technologies. These high-technology responses to changing markets require a highly skilled labour force capable of running the complex control systems associated with transformation processes.

- Advanced control systems for process management: Improved control is driven process considerations of accuracy, reliability, monitoring and product traceability as well as by environmental considerations. This bears on the reliability and control of waste and emissions from a production process. In sensitive subsectors this will require external accreditation of the control systems.
- Clean production: Clean production is a generic title for the developments associated with production technologies and systems. Government regulation is increasingly becoming a major driver for this issue.

2.3.3 New or improved materials inputs

Enhanced functionality and issues of size and weight drive the search for new or improved materials. Demands for sustainability are focusing attention on developing the use of replaceable materials and re-usable materials.

- Production of new materials: This process is driven by the need to produce more from less, and affects all segments of manufacturing. Specific technology areas include advanced magnetics, micro-structured photonic materials, high temperature superconductors, and high temperature metals and structural ceramics.
- Waste minimisation: Sustainability requires that resources must be conserved and unnecessary material usage eliminated. Whilst seemingly straightforward, the realisation of this element in order to conserve limited resources will be the cornerstone of tomorrow's manufacturing. It requires attention to design and process specifications as well as the manufacturing system used.
- Combining materials: The search for better materials leads to a focus on combining the complementary characteristics of different materials. Future R&D will focus on applications of adhesion, thin-layer films, molecular and atomic layer depositions to produce superalloys, intermetallics and composites.

2.3.4 New manufacturing systems

It is of critical importance to turn new or improved technological developments or solutions to economic effect. Demands for variety and quick delivery can only be met by improved organisation of facilities and logistics. Diversity is a growing feature in manufacturing, and it is rapidly causing traditional approaches to ownership and control of capacity to become obsolete. The areas of focus are the following:

- Integrated product, process and production system design: To speed up their response time, manufacturers have turned to concurrent engineering, where design and approval are configured into a parallel, iterative process. However, demand patterns continue to change at an ever-faster rate, increasing the need for agile production. This requires integrated product, process and production systems. This trend will impact heavily on the discrete product production segment, especially consumer goods. Requirements for the continuous upgrading of telecommunications equipment also drive this trend. Process engineering, materials, and organisational concepts are all affected by this trend.

- Reconfigurable equipment: Production equipment generally represents a major capital investment and a medium-term commitment to earn a return on investment. However, the new patterns of demand require high variety and low volumes, and this puts the economics of production under increasing pressure. Reconfigurable equipment reduces the need for costly and disruptive re-fitting of capital-intensive areas of production. This will have the most impact on discrete product production, especially the fast-moving consumer goods section. Specialist operators with knowledge of various technologies will be required to operate in organisations with advanced structures.
- Integrated production planning and control: The integration of production management and logistics is essential for completing the configuration of new manufacturing systems. Although some work has been done on integrated manufacturing systems, much still needs to be done.

2.3.5 New organisational concepts

Increased functional integration and continuous, rapid change are creating new requirements for organising people and their contribution to the overall business process. Learning curves are also being shortened as the ever-increasing number of new technological developments demand different skills and capabilities. The areas of focus are the following:

- New manufacturing paradigm: Volatile demand patterns for high-variety products, and the need for a speedy response by manufacturing systems, have rendered obsolete most of the traditional paradigms governing production planning and management.
- Multiskilling: In addition to broadening the skills base, continuous upgrading and acquisition of skills appropriate to the demands of the future environment are becoming essential. The rapid changes in technologies being adopted require constant upgrading and diffusion of skills among workers.
- Benchmarking best practice: In developing competitive manufacturing organisations for the future, an important element of success will be performance matrices that serve to guide and energise companies. In order to stay competitive, companies will need to develop organisational frameworks that permit stand-alone and integrated, sector-wide benchmarking.

2.4 South African Position

Because of South Africa's recent economic isolation it had to fend for itself and develop an in-house research and development capacity in the manufacturing/materials sector in support of industry needs. This was especially evident in the high level of in-house competency in the armaments technology industry, which forms part and made extensive use of the manufacturing/materials sector of industry. Although this isolated emphasis was not the most economically effective way of developing the manufacturing sector, it nevertheless provided an opportunity for the local labour force to develop valuable skills that could still prove of immense value, if retained and applied correctly.[1]

The most reliable gauge of a country's benchmark position in relation to technology is to consider the ratio of gross expenditure on R&D (GERD) to national GDP. The GERD/GDP ratio for South Africa across all manufacturing subsectors is 0,9 per cent. Comparison figures are shown.

Country	Year	As percentage of GDP total
Hong Kong	1995	0,1
Singapore	1992	1,0
Korea	1993	2,3
Taiwan	1993	1,7
Indonesia	1993	0,2
Malaysia	1992	0,4
Thailand	1991	0,2
China	1992	0,5
India	1992	1,0
Pakistan	1987	0,8
South Africa	1997	0,9
Japan	1992	3,0
France	1991	2,4
Germany	1989	2,8
UK	1991	2,1
USA	1988	2,9

Research and development expenditures, by country (source: Lall 1997)

South Africa's GERD/GDP ratio is similar to that of Hungary, Spain, Portugal, Chile and Brazil, but remains well below the 2% average for the industrialised countries and leading nations such as Japan and the USA. An additional fact to take into account when doing such a benchmarking, is the high disparity of research spend within subsectors of the manufacturing sector. The table below shows that R&D spend is particularly strong in the aerospace, professional goods and communications subsectors, but that overall R&D spend is low, especially in sectors where latent economic advantages lie untapped.

In closing, it is important to note that while South Africa appears to invest an adequate, if not substantial, percentage of its GDP in R&D given its developing nation status, it is worrying firstly that such R&D spend is so concentrated in a relatively few subsectors, and secondly that sectors which have been losing marketshare since the reduction of trade barriers do not appear to be investing in R&D to catch up with their international competitors. A more worrying concern is that this percentage spend has decreased substantially since 1993. This last indicator infers that R&D spend is becoming less important in the short term as the country struggles to redress inherited imbalances from the former socio-economic system. An additional concern is that South Africa has failed to harness R&D and innovation development within the small-business sector, which internationally is the most robust source of R&D and innovation. Problems concerning access to capital, technological take-up, access to business skills and technology diffusion all need to be addressed in a systematic methodology.

Existing shortsightedness in these areas may undermine the foundation upon which manufacturing can build its ideal position within the national strategy. Manufacturing should become the golden goose of increased export earnings and job creation.

Sector	Gross output (R millions)	R&D expenditure	R&D expenditure per gross output (%)
Food beverage and tobacco	43 053	80,29	0,19
Textiles	16 006	9,96	0,06
Wood products and furniture	6 486	7,04	0,01
Paper, paper products and printing	16 626	7,87	0,05
Chemicals ex drugs	7 840	178,88	2,28
Drugs	3 680	27,38	0,74
Petroleum refineries	14 028	27,34	0,19
Rubber and plastics	8 237	27,99	0,34
Non-metallic mineral products	7 215	19,86	0,28
Iron and steel	14 343	28,55	0,2
Non-ferrous metals	4 358	40,51	0,93
Metal products	15 408	19,45	0,13
Non-electrical machinery	12 552	246,85	1,97
Electrical machinery	6 147	85,63	1,38
Radio, TV and communications	2 710	139,1	5,13
Motor vehicles	19 275	79,79	0,41
Aerospace	600	74,33	12,39
Other transport equipment	466	2,49	0,53
Professional goods	847	55,52	6,55

Chapter 3:

Internal And External Environmental Analysis

3.1 Introduction

STEEP and SWOT are methodological tools that the Sector Working Groups utilised to give a picture of the current status within each sector. STEEP includes major Social, Technological, Environmental, Economic and Political factors that collectively brush out the landscape within which the manufacturing and materials sector is contextualised. STEEP factors are therefore the environmental externals that exist and impact on the sector's current operations as well as its future prospects.

SWOT analyses the sector's specific Strengths, Weaknesses, Opportunities and Threats and is therefore a more focused tool than STEEP.

Together, the STEEP and SWOT analyses in this chapter add substance and depth to the general benchmarking completed in the previous chapter. These two analyses will be carried forward in the next chapter as inputs into the four possible Foresight scenarios.

3.2 STEEP

STEEP factors are characterised into two groups. 'Drivers' are broad social, technological, environmental, economic, and political factors that propel nations and world communities in a particular direction. For example, a social driver in South Africa is the desire to increase the standard of living of the population as a whole. The second category of STEEP factors involves 'constraints'. These are factors that inhibit or impede the achievement of desired national outcomes. For example, a social constraint on increasing the standard of living of South Africans may include high levels of unionisation and low productivity.

South Africa's STEEP factors are shown below in Table format. STEEP factors apply equally to both the materials and manufacturing sectors, therefore no differentiation is made in the determination of the four tables.

Social factors	
Drivers	**Constraints**
Wealth creation and the distribution of such wealth so as to narrow the Gini coefficient Need to decrease the unemployment rate Drift towards first-world standards and eradication of third-world characteristics such as 'avoidable' disease and child labour Improved standards of living for the majority of citizens, e.g. access to housing, water and electricity Demographic profile of a large, young population Spirit of entrepreneurship Need to develop a culture of learning Outcomes-based education and inspired educators Patriotism for the success of a new democratic South Africa Desire for instant delivery AIDS	Brain drain Low productivity Poor work ethic, coupled with a culture of entitlement Poor management of workplace diversity Lack of quality/service culture Inadequate skills base Poor match between skills supply and demand High degree of automation replacing people White-collar crime Excessive government regulation State ownership Unionism Attractiveness of 'clean jobs' Consequences of the spread of AIDS Lack of management skills Lack of appropriate social indicators Resistance to automation Lack of appreciation of SA products Crime Entrenched mindsets Poverty

Although these social factors are varied, they essentially deal with the drive to establish a higher standard of living given our legacy of the past and the fact that South Africa suffers from inequalities deriving from having a dual first- and third-worldculture and economy. The constraints are largely the limitations of our human resource pool and the issues facing a labour-rich economy in a world of growing technology and automation.

Technological factors	
Drivers	**Constraints**
Internet Biotechnology Miniaturisation Smart materials Light materials Autonomous intelligence Role of partnerships Shorter product life cycle Maintenance of privacy through delivery of information Reducing transaction cost Mass customisation Niche market development Movable production units Information technology (IT) Long-distance audio-telecom Integrated factories Disposable products Rapid delivery system	High cost of capital State monopolisation of key industries Limited knowledge in active materials Limited knowledge in miniaturisation Absence of primary infrastructure Ineffective mechanisms to manage technological innovations Lack of benchmarking Water scarcity Insufficient education and training to support the development of a technology culture Dependence on overseas industries and technology

With regard to technological factors, the drivers moving South Africa include the technological and associated business methodology of the more sophisticated technological world leaders. On the constraints side of the equation, are inputs into the production process, namely labour and capital.

Economic factors	
Drivers	**Constraints**
Worldwide investment mobility Productivity Wealth creation Globalisation Regionalisation Trade liberalisation Linkages between manufacturing and service provisioning Customer focus replacing product focus Interest-rate management Job creation Redistribution of wealth Access to global finance	Tax rates Red tape Lack of venture capital markets Small domestic and regional markets Distance from major markets High internal/external transport costs Inflation Business confidence Relatively low levels of rivalry Poor global image Intellectual property rights Uncalibrated yardstick

The economic environment analysis impacts on the entry of a previously isolated and highly protectionist state. The state now has to merge into an international arena characterised by globalisation and new business methods. Having been isolated for two decades, the South African economy enters such a stream on a weak footing.

Ecological factors	
Drivers	**Constraints**
Global concern with sustainable development Exploration for renewable resources Codes of standardisation Exploitable biodiversity Water availability?	Cost and knowledge involved in better management of environment – ISO 14000 Shorter product life cycles Emergence of back-door manufacturers Cost of environmental repair Water scarcity

With regard to ecological factors, South Africa faces similar constraints and drivers to those faced by the rest of the world. The main focus is on more environmentally friendly production, especially in terms of recycling, given the trend towards shorter product life cycles.

Political	
Drivers	**Constraints**
Trend towards regionalisation Window of opportunity for the new SA Stability of governments with transparent policies Desire for equality Government commitment to instant delivery Labour practices Persistence of racial discrimination	Fear of exploitation Lack of coordinated industry strategy Poor global image Political uncertainty Cost of transition to democracy Political time frames

The political issues facing South Africa are two-fold. The first set of issues relate to stabilising and normalising the domestic situation; while the second set of issues relate to external positioning both with regard to SADC and the broader international market.

3.3 SWOT

Substantive input into the manufacturing and materials SWOT was arrived at through four main methods. First, extensive desk-top research was undertaken. Secondly, industry trade shows were visited. Thirdly, experiences from Working Group members' international exposure were collected, and finally the topic was thoroughly workshopped.

It comes as no little surprise that many of the STEEP issues identified re-appear in the SWOT analysis. This is an important issue to flag as it shows the inter-connectivity between specific sectors and the broader environment. Manufacturing and materials do not exist in isolation and the strengths, weaknesses, opportunities and threats of the sector to a large extent mirror the drivers and constraints of the national environment as a whole.

Once again, the SWOT is presented for the manufacturing and materials sector as a single SWOT, although certain bullet points apply especially to one or the other sector, as indicated below.

3.3.1 Strengths

Below are the key strengths and weaknesses facing the South African manufacturing and materials sector. A complete list of the Working Groups' output with regard to these strengths and weaknesses is found in Appendix 3.

Geographical position

South Africa is well positioned to increase South-South cooperation with mass-market developing countries in Southeast Asia as well as China, India, and the east-coast countries of South America. South Africa is also well positioned as an entry point into sub-Saharan Africa.

Natural resources

South Africa has been blessed with an abundance of natural resources that have the potential to be an enormous strength for the nation's future growth prospects. The country has an abundance of gold, manganese, chromium, platinum, vermiculite, coal and other minerals, as well as the third cheapest electricity in the world, the largest aluminium smelter in the world, the largest single-site stainless-steel plant in the world and the cheapest gate cast iron in the world.

Military and fuel technology base

Because of former government policies, South Africa invested heavily in the development of substantial capabilities in defence and fuel provision in the interests of national security in the 1960s, 70s and 80s. This formidable base as exemplified by SASOL, AEC, Denel and Armscor created a strong technological base for the country in terms of investment, know-how, products and skills.

Strong R&D institutional base

South Africa has amassed a formidable institutional base for general and technological skills development in excess of that available in most comparable developing countries. This infrastructure includes world-class tertiary education institutions, medical and veterinary research institutions, and nine nationally financed research councils.

Infrastructure

South Africa boasts first-world infrastructure in the majority of its urban nodes. Strong communication and physical infrastructure relative [comparable?] to that of other emerging-market economies provides South Africa with a strong base for future growth.

Appropriate technology

South Africa has shown an ability to apply first-world technologies to developing country needs and is recognised as a world leader in certain niche markets.

3.3.2 Weaknesses

Low degree of specialisation

Because of the country's former policies of self-reliance and import substitution, local manufacturers and producers of materials have failed to specialise in sectors in which they have a competitive and comparative advantage, producing instead a broad spectrum of goods in all subsectors. As a result, South Africa has the third lowest level of specialisation in the world, and with this failure, the country's manufacturers fail to reach economies of scale and therefore are not internationally competitive.

Labour market

The South African labour market suffers from weaknesses in terms of such 'hard issues' as comparatively high unit labour costs, poor labour skills and low productivity, as well as 'softer' labour market issues such as adversarial management, [poor?] union relations, poor work ethics and practices and poor workplace diversity management. Management of the nation's labour force is considered to be weak despite recent advances exemplified in better labour relations and increased productivity.

Resource curse hypothesis

South Africa has historically relied on its abundance of raw materials to generate growth in the economy, while other sectors have been less well developed. In the shift from the industrial age to the information age, this lack of focus on non-primary sectors is starting to become increasingly prominent. With regard to outputs such as pricing and exports, and also in terms of training and cultural focus, we need to move away from the country's faith in its natural resources as its continuing golden goose.

Lack of competition

While much has been said in previous chapters about the negative effect of South Africa's isolation from the international economy in terms of manufacturing competitiveness, a lack of domestic competition has played an equally important role. The local manufacturing and materials sector have historically been largely concentrated in the hands of a small stable of companies and parastatals. Rivalry between firms in the local market is extremely low. There has been limited pressure for monopolised or cartelised manufacturers to innovate, research or develop better or cheaper products.

Market constraints

The South African market is small and unsophisticated in terms of both numbers and spending power. In addition, South Africa's legacy of poor information collection, and limited information sharing has resulted in a relatively apathetic demand and uninformed supply system. This limits the market's profitability and attractiveness in comparison with other international markets.

Supply chain gaps

Because of many of the issues already described, South Africa has developed a manufacturing system that has serious gaps in the supply chain. These gaps are likely to be filled with international inputs or technologies that are often inappropriate or extremely costly. Furthermore, there is support for the position that local firms are not correctly placed within the supply chain as it currently exists. Dealing with this issue requires a strong national industrial policy that at this time is absent, representing a major weakness in the development of the manufacturing sector for the next millennium.

Capital costs

South Africa continues to be largely reliant on imports of capital equipment and machinery. Owing to the devaluation of the rand and BOP constraints, the high cost of imported capital will remain a weakness in the local manufacturing sector that will continue to impede increased competitiveness.

Lack of R&D

As shown in the previous chapter, insufficient expenditure on R&D within the materials and manufacturing sectors continues to weaken the country's future positioning in the world market, given the high levels of R&D that are now required to meet increasingly sophisticated demand by consumers of manufactured goods.

3.3.3 Opportunities

Based on the country's strengths and weaknesses, the following checklist of possible opportunities was arrived at:

- The need to develop an export basket mix that exploits the low exchange rate and price elasticity of manufactured goods.
- Increasing productivity through the more extensive and effective use of our communications and IT infrastructure capacity.
- Value-adding service through product diversification, beneficiation and high value added production.
- The need to fully exploit our geographic advantage and transport infrastructure.
- The need to exploit our window of opportunity as the world's democratic darling to establish beneficial strategic alliances with international players at both the national and the corporate level.
- In the current spirit of goodwill we need to expand negotiation and networking forums in order to harmonise relations within and between the education sector, the science sector, the private sector, the public sector and labour.
- We need to exploit our labour-cost advantages at the high end of the skills market.
- We need South Africans and international players to realise the true depth and advantages of South Africa as a viable R&D destination.
- We need to continue commercialising defence and strategic technologies and increase technology adoption in the manufacturing sector.

3.3.4 Threats

The major threats facing South Africa are the following:

- Failure to meet global business standards such as ISO 14000.
- Economic sabotage.
- Competition for investment funds/finance from other developing countries.
- Imported grey market products that undermine the local formal manufacturing sector.
- Inability to solve labour market issues and a failure to increase management and labour productivity.
- White-collar and blue-collar corruption.
- International crime syndicates.
- Decline in investment in R&D and education and other intellectual infrastructure.

- Failure to change South Africa's mindset about the realities of competing in a global environment.
- Regional migration.
- Commodity price reduction.
- A decrease in the demand for materials.
- Environmental pressure if dirty technology is used.
- Continued brain drain.
- Inability to exploit opportunities.
- Inability or unwillingness of industry to re-engineer so as to harness economies of scale in focused markets.
- Failure to collect, disseminate and assimilate increasing information overflow.
- Failure to keep pace with manufacturing best practices and technologies.
- Allocation of resources away from the productive side of the economy towards social spending.

Chapter 4: Scenario Planning

4.1 Background to Scenario Planning

The Foresight methodology uses scenario planning as opposed to a master planning or forecasting approach when considering future uncertainties. Scenarios are stories about possible futures that —

- are about what *could* happen, not what *will* or *should* happen;
- are internally consistent;
- are useful and challenging;
- contain predetermined (relatively certain) elements and key uncertainties and
- are neither predictions nor forecasts.

Forecasting and master planning techniques tend to be more useful when planning under circumstances where variables are few in number and their inter-relationships are easily defined. Scenarios tend to be more useful when planning under circumstances where variables are many in number and their inter-relationships are complex. The table below compares the two approaches:

Comparison of planning methodologies

Forecasts	Scenarios
Single line, impoverished	Multiple, rich stories, projections
Predictability	Unpredictability and influence
Focuses on certainties	Focuses on uncertainties and possibilities
Conceals risks	Clarifies risks and opportunities
Fosters inertia and reactivity	Encourages responsiveness and creativity

Scenarios are intended to improve the quality of strategic thinking and conversation and challenge mental models and conventional wisdom. They allow planners to 'prototype' strategies and to anticipate and recognise change.

4.2 Summary of Generic Foresight scenarios

Four generic scenarios were developed under the Foresight process. These scenarios are common to all Foresight sector working groups. The development of these scenarios is described elsewhere in the Foresight report. In order that the re-port for the Foresight Manufacturing and Materials Sector may be read independently from the rest of the reports, a summary is provided below.

Four scenarios were chosen for being relevant to the Foresight process. They were The Global Home, The Innovation Hub, The Frozen Revolution and Our Way Is The Way.

The various scenarios can be classified succinctly by the typology shown in the table below. This uses as major categories the extent of societal linkages and the degree to which these are external/internal to South Africa.

Scenario typology

	Fragmented society	**Linked society**
External locus	Global Home	Innovation Hub
Internal locus	Frozen Revolution	Our Way Is *The* Way

The political, social, economic and technological dimensions of the four scenarios are summarised in the following table.

4.3 Process Followed by Manufacturing and Materials Working Group

The process followed in determining the impact of the four generic scenarios on the manufacturing and materials sector was as follows:

- Key uncertainties and their impact were developed for each scenario. These uncertainties and impacts were summarised and recorded.
- The SWOT of the manufacturing and materials sector as summarised in the previous chapter were analysed against the framework of each scenario.
- The results of each of these steps are documented in the sections that follow.

	Innovation Hub	**Global Home**	**Frozen Revolution**	**Our Way Is *The* Way**
Political	Regional alignment with global view, directed development via innovation, some loss of national identity	Global alignment, diminished role for government, private sector dominant, dissolution of national boundaries and identities	No consistent alignment, interventionist on a reactive basis, fragmentation of national identity	Global alignment, but on our terms, withdrawal from global agenda,self-determination, strengthening of national identity
Social	Regionally directed long-term plan for incremental development, rich-poor gap remains, but number of poor decreases, innovation-directed education	No direct social development plan, rich-poor gap increases, but number of poor decreases, global market-related learning	Several social development plans and policy, but no delivery, rich-poor gap increases, number of poor decreases, undirected, low relevance learning	Focused social development plan, rich-poor gap decreases, number of rich decreases, life-long learning toward knowledge-based society
Economic	Proactive economic policy, SADC-focused, mostly open market, high international investment, initial GDP < 2%, but slowly increasing	Reactive economic policy, globally focused, open market, high international investment but within private sector, initial GDP > 2%, but slowly decreasing	Reactive economic policy, indeterminate, partially open market, international investment capital intensive, initial GDP < 2%, but decreases to negative	Proactive economic policy, focused on developing world, partially open market, very limited international investment, initial GDP < 2%, but slowly increasing
Science and technology	Active promotion of innovation and technology management, appropriate technology developed locally, foreign technology adapted by licence	S&T driven by global forces, global access by licence	Low emphasis on S&T, but emphasis on populist projects, S&T sourced almost exclusively from elsewhere	S&T aimed at self-sufficiency, access to global S&T capacity and information by all means possible

4.4 Sector Key Uncertainties

Key uncertainties and the impact of these uncertainties were developed for each scenario as applicable to the manufacturing and materials sector. These are listed in the table opposite.

4.5 Opportunities and Threats

As the strengths and weaknesses of the two sectors were dealt with in detail in the previous chapter, the remainder of this chapter seeks to analyse the threats and opportunities of the manufacturing and materials sector against the framework of each scenario. A summary of the salient points is presented below, and a fuller analysis is contained in Appendix 3.

4.5.1 Innovation Hub

In general, the opportunities inherent in the Innovation Hub scenario are those of globalisation. They include sustainable economic growth combined with job creation (for both higher and lower skills levels). The scenario presents the opportunity to take advantage of the sector's first-world strengths and to apply those strengths to the promotion of development in the Southern African region. This scenario also presents the opportunity to make the most of the region's natural resources (such as hydropower and water) for the development of the region as a whole.

The threats inherent in the Innovation Hub scenario are largely related to the vagaries of the small local (Southern African) market. They include corruption, tariffs, political unrest, size (it is too small to reach even minimum economic size) and exchange rate fluctuations. The threat of non-uniform environmental standards (and other externalities) in the market could threaten the viability of South African companies and affect the quality of life of the entire region.

4.5.2 Global Home

In general the opportunities inherent in the Global Home scenario are also linked to globalisation. Technology, skills and capital will move quickly into South Africa, promoting development and growth. Large-scale privatisation and a relatively free regulatory environment will provide opportunities for private supply of utility and other services, attracting multinational companies.

The threats inherent in the Global Home scenario are largely related to the mobility of factors of production. Human and financial capital will move quickly after better opportunities resulting in a 'boom or bust' economy, with concomitant problems such as labour unrest, exchange- and interest-rate fluctuations, low fixed investment and low R&D investment.

Key uncertainties

Key uncertainties	Innovation Hub	Global Home	Frozen Revolution	Our Way Is The Way
Debate between environment and development lobbies	Development will dominate with consideration of international environmental requirements	Development will be the issue, with less emphasis on environmental concerns	Decay/status quo and environmental issues probably inconsistent	Balance between local value system and development
Job creation and retention	Little job creation initially but long-term, sustainable job creation	Initial job creation, but not sustainable	Very few manufacturing jobs, initially service-oriented, but not sustainable	Initially positive impact, but long-term sustainability questionable owing to competition
High cost of capital including interest and tax	Reduced cost of capital	Local industry and start-ups very vulnerable: multinational companies rule	Primary projects go ahead but not other manufacturing concerns. Low-value-added industries and high taxes	Limited access to international capital. Interest gets worse, with high tax
Unequal distribution of and ability to create and sustain wealth	Little redistribution of wealth but increased distribution of ability to create wealth	Some redistribution of wealth but deterioration of distribution of ability to create wealth	Some redistribution of wealth but not too much creation of wealth	Globally oriented government
Poor control of global distribution channels	Distribution more consciously on agenda and leveraging possible	Multinationals dominate and local business weak, government weak and reactive	Long-term, very few options, likely deterioration	High entry barrier. Form our own channels, cost of saying 'get lost' very high
Lack of synergies between redress and socio-economic development	Better synergies with emphasis on development	Deterioration of synergies	No systematic plans/synergies	Emphasis on redress and some improvements of synergies
Small local markets and large, distant international markets	Stability through less dependence on international markets	Gets worse, less control	Life as usual but shrinking value of exports	Local market grows, incompatible internationally
Impact of changing weather patterns	Regional cooperation on water resources and technology	No national attention to the problem, water-thirsty industries disappear	No consideration of environmental sustainability	Attention to problem with no external input, focus on local knowledge
Vision and growth of negative paradigms	Long-term vision and morale improve, short- to medium-term risk	No common vision, negatives remain with pockets of positive morale	Short-term vision, morale up and down	Vision (only SA-specific), morale mostly positive
Insufficient access to risk capital	Strong drive owing to access to risk capital	No risk money, only capital	Expedient risk projects financed by government	Addressed by drive for self-sufficiency
Skills base for technology in society lacking	Problems solved by active S&T	No 'active pipeline' in place	Undirected and low-relevance learning and training	Addressed by drive for self-sufficiency

4.5.3 Frozen Revolution

The opportunities inherent in the Frozen Revolution scenario are those created by society's inability to create a common vision and direction. This includes the maximisation of opportunities resulting from the lack of service delivery by government in the fields of health care and utilities. The lack of a functioning regulatory environment will provide opportunities to make short-term profits from the existing infrastructure and assets, with the ability to pay low wages to the unskilled.

The threats inherent in the Frozen Revolution scenario are largely related to the lack of sustainability in economic activity. The eventual capital and skills flight, unemployment, plundered resources, crime, corruption, etc. will lead to the breakdown of ordered society.

4.5.4 Our Way Is The Way

The opportunities inherent in the Our Way Is The Way scenario are related to the provision of those goods and services that are not available from international markets because of isolation or incompatibility with 'Our Way'. Local expertise in industries, for example nuclear and coal gassification, will provide opportunities for high-level skills development.

The threats inherent in the Our Way Is The Way scenario are largely related to the cost of funding inappropriate indigenous technologies and industries and of 're-inventing the wheel'. This will lead to isolation and gradual divergence from international markets and norms, and eventually to a non-competitive economy.

4.6 Analysis of Scenario Study

A multitude of rich yet unpredictable tapestries can be woven from the content above, explaining the potential scenarios facing South Africa's manufacturing and materials sectors.

South Africa's manufacturing and materials sectors indisputably possess critical strengths and face sufficient opportunities, so that these sectors can continue to contribute to the country's growth and development and even flourish in the local and international market.

The greatest threat to successfully harnessing these opportunities and this solid foundation is a failure to adopt the correct policies, both with regard to national prioritisation and within the sectors themselves.

Given the strengths, weaknesses, opportunities and threats facing these sectors, the most supportive scenario for their future growth would be the Innovation Hub followed by the Global Home. Either of the internally focused scenarios would fail to harness the industry's potential and to address national developmental needs. This would send the country spiralling into increased social and political instability, thereby undermining the future of the sectors themselves.

The most important analytical conclusion drawn from this chapter is that South Africa is fortunate enough to have both a manufacturing and a materials sector with pre-existing potential of the highest magnitude. The challenge is one of harnessing and converting this potential in an optimum manner.

Chapter 5:
Survey, Analysis and Results

5.1 Introduction

The questionnaire-based survey is a core tool within the Foresight process. It is a consultative process designed to assess and evaluate the various issues that were identified by the Sector Working Group. This process allows the Foresight process to test the thinking of the future by the sectors' stakeholders. They are knowledgeable or expert people in the sector who have been identified by the Working Group and a rigorous co-nomination process. All the people to whom the survey was sent and who returned completed surveys are regarded as the 'stakeholder group.'

5.2 Survey Methodology

The concept of the survey was based on similar work that performed internationally. In this process, a number of topics or issues are tested against a number of variables. The variables selected are the same for all the sectors in the Foresight project and are therefore not tailored, nor optimal, for the manufacturing and materials sectors.

The respondents were asked to give their views on a range of topics selected by the Sector Working Group. This was followed by a second-round survey in which the respondents were given an opportunity to review their response in light of the collective opinions expressed in the first-round questionnaire. This made it possible to attach greater significance to those statements that were given a high level of confidence by the respondents. This method has been used for over 30 years and is the basis of several successful overseas foresight programmes and similar initiatives.

5.3 Survey Process

5.3.1 Survey format

The Foresight project team, during the course of a number of workshops, developed the format of the survey and the variables to be used. The difficulty of such a task was to develop a standard list of variables that would have meaning in all 12 sectors involved in the project. The basis of the variables was an attempt to include questions that would provide a snapshot of where technology in South Africa stood at present and, at the same time, indicate how important it was for the country in respect of wealth creation and quality of life, and also through the development of strategies and timescales for acquiring these technologies.

The survey format made allowance for the respondents to add comments, formulate alternative statements or add new topics to the questionnaire.

5.3.2 Development of relevant statements

The Sector Working Group developed the statements during two workshops and by working in two groups. The group began by analysing the material presented in the first four chapters of this study and then identifying seven topics within which statements would be developed. A first round of statements was generated in a brainstorming workshop. These statements were then refined according to criteria established by the Foresight project leaders, who agreed, amongst other things, that —

- statements should test only one idea;
- statements should have a futuristic element;
- statements should be closed and not open ended;
- 70% of the questions should be focused on research and development;
- 30% of the questions should deal with generic and policy issues;
- the questions should answer 'why?' and 'is it possible?' types of questions;
- all statements should include three components:
  - an idea;
  - a specific issue/objective/use application; and
  - an indication of the 'state of development' of the particular statement.

5.3.3 Structure of the survey questionnaire

The Manufacturing and Materials Sector questionnaire consisted of 61 statements, categorised into seven topics or focal areas:

a) Customer linkages and the supply chain.
b) Smart materials/new materials.
c) Information technology and automation.
d) Manufacturing's best operations/new processes.
e) New processes.
f) Education and training/capacity development.
g) Others.

The structure of the survey questionnaire is shown in the table below:

Topic	No. of statements	Percentage
Customer linkages and the supply chain	13	21
Smart materials/new materials	6	10
Information technology and automation	5	8
Manufacturing's best operations/new processes	11	18
New processes	17	28
Education and training/capacity	4	7

An analysis of the table clearly shows the importance of new processes in the minds of the Working Group. The rapid rate of technological change and the application of new technologies to what is manufactured and how goods are manufactured were viewed as the most important determinants of the future of the manufacturing and materials sector's ability to create wealth and improve quality of life. These views were felt to be more pronounced in South Africa, where the manufacturing sector was struggling to be internationally competitive with regard to its product offering.

The second most important topic was felt to be customer linkages and the supply chain. The importance of this topic in relation to this specific Working Group relates to the fact that manufacturing is largely demand-driven, with final consumer preferences and views being crucially important are the supply decisions of the manufacturer or materials producer. As such, links to customers and markets as well as the efficiency of the complete supply chain are extremely important.

In line with the criterion that the survey statements should focus on research and technology, only 15% of the survey questions dealt with softer, more generic issues such as capacity building and the legislative environment.

It is important to note the structure of the questionnaire. As will be shown later, the rate of responses to the topics did not coincide with the priorities evident in the construction of the survey.

5.3.4 Conducting the survey

Survey questionnaires were issued to 1 486 stakeholders and interested parties, including the major manufacturing associations in all 27 manufacturing subsectors, parastatals, academics, all eight research councils and high-level managerial and technical individuals in the private sector.

The survey was available in both paper and electronic format, and a Foresight website was established. In hindsight and for future Foresight exercises it is suggested that specific awareness campaigns be initiated to sensitise recipients of survey questionnaires to the fact that they are about to be issued and to their strategic importance for policy and sectoral development. This we believe will improve response rates. It is also suggested that a broader, more inclusive stakeholder group be considered and that the entire Foresight process be given more publicity and be better marketed.

5.4 Survey Results

5.4.1 Response

Of the 1 486 questionnaires that were distributed, 150 were returned, representing a response rate of 10,09%. While this figure seems low, international comparisons show that this is a good response taking into account the length and the complexity of the questionnaire.

5.4.2 Analysis of the top twenty statements

Refer to the table below

5.4.3 Analysis of the overall results

The Human Sciences Research Council (HSRC) undertook the analysis of the results of the first survey according to internationally accepted norms. The overall results of the survey are given in the appendix.

Several conclusions were drawn from the analysis of the survey and these will be given below. In order to analyse the statements, three indices were developed, namely the wealth creation index, the quality of life index and a joint index, which is an average of the first two indices.

No.	Topic	Joint Index	WC Index	QL Index	Constraints
54	Tertiary education institutions (universities and technikons) will transform so as to ensure high quality, appropriate skills development to support a strong manufacturing base.	91,94	93,55	90,32	HR, P, F, Soc./Cul.
06	Widespread availability of venture capital to enhance the innovation of new products and processes in South Africa.	89,29	83,33	82,14	F, P
04	Practical implementation of industry-specific clusters in South Africa that will result in an ability to innovate and compete in world markets.	85,63	93,48	77,78	P, HR, F, M
58	Government's appropriate trade and legislative framework will support local industry to meet challenges of international competition.	85,42	87,50	83,33	P
07	Widespread use of intelligent communication systems that will enable SMMEs to effectively integrate their skills and knowledge with industrial partners of their choice to form a wealth-creating business.	74,32	78,38	70,27	F, HR, T
60	International transfers and relationship building at public- and private-sector level will tangibly help South Africa to use leapfrog technologies to forge ahead.	74,32	75,68	72,97	P,HR,Fsoc/Cult
32	Management of new process innovation will be a key success factor for most SA companies in future.	74,07	81,48	66,67	HR, T, Infrastr.
08	South Africa's manufacturing production will be predominantly characterised by raw material beneficiation through training of downstream processors on value chain management, design and fabrication technology.	72,55	78,43	66,67	HR, T, F

No.	Topic	Joint Index	WC Index	QL Index	Constraints
03	Practical application of free-trade zones that will facilitate a regulatory framework for importers and exporters to maintain manufacturing standards in the country of product origin leading to the world economy.	69,71	81,08	58,33	P
11	South Africa becomes niche-focused in its manufacturing industry and thus becomes a world leader in a limited number of products	67,27	70,91	63,64	T, HR, Infrastr., F
09	Mass customisation of products, reduced product life cycle, shorter lead times, etc. Will become an important driver for South African suppliers to maintain market share on a global basis.	65,63	77,08	54,17	T, HR, F
25	Widespread use of practices to eliminate variability in practices and processes is fundamental to competitive manufacturing.	61,46	72,92	50,00	HR
61	Widespread use and adherence to international environment and quality standards like ISO9000, ISO14000 and QS9000, VDA6, the SABS series, etc. by South African companies to become competitive and internationally recognised.	60,29	62,12	58,46	HR, P, F, Soc./Cult.
57	In the future, access to mainstream economic and social activities will discriminate between technologically literate and technologically illiterate individuals and groups.	58,47	56,41	60,53	HR, Soc./Cult., P, F
12	South Africa's manufacturers develop small-batch manufacturing capabilities for a competitive edge.	58,16	65,31	51,02	T, HR, F, M
31	Development of recycling industry (water, raw materials) that will result in waste-free manufacturing.	57,14	42,86	71,43	T, P, F
46	Widespread use of concurrent engineering technologies, namely CIM, CAD, CAM, etc. to improve time-to-market by South Africa's manufacturing industries	53,41	68,18	38,64	HR, F, T
29	Widespread use of industrial design skills where designer materials will be a fundamental part of new products in the future.	53,13	62,50	43,75	HR, T, F

Characteristics of the Bottom 10 Statements with High Confidence

No.	Topic	Joint Index	WC Index	QL Index	Constraints
47	Widespread use of biological structures (biotechnology) in engineering design, fabrication of parts and assemblies with biological processes; designer proteins, enzymes and tissues, biocatalysts; bio-assembly of new foods and bio-devices for computer memories.			14,29	T, Infrastr., HR, F
15	Development of semiconductor manufacturing technologies in South Africa that are concerned with the creation of smaller structures for semiconductor chips using silicon-based methods.	5,00	16,67	-6,67	T, Infrastr., F
43	Development of biomimetic systems that synthesise proteins using natural and non-natural amino acids.	-2,17	-21,74	17,39	T, F, Infrastr.
19	Development of 'smart buildings' that offer real-time information about energy usage and costs by allowing building owners and tenants to become more energy efficient.	-3,79	-4,88	-2,70	T, F, Soc./Cult., M
42	Development of micro- and nano-technologies for fabrication processes, for example, atom-by-atom fabrication of assemblies and development of micro-scale machines.	-5,50	-25,71	14,71	T, F, Infrastr.
	Strengthening of the relationship between consumption, production and advancements in networking between stores				

52	Development of semiconductor manufacturing technologies in South Africa that are concerned with the creation of smaller structures for semiconductor chips using silicon based methods.	-20,37	-33,33	-7,41	F, T
18	Development of ceramic materials for high-temperature gas turbines that have a self-repairing ability for damage (e.g. preventing cracks, corrosion, etc.) in a combustion atmosphere.	-21,88	-40,63	-3,13	Soc./Cult.
24	Development of semiconductor-integration technologies that contribute to harnessing information technology by reducing the cost of components for computing systems and by creating multi-chip modules that allow faster movement of electrons between integrated circuits.	-32,69	-30,77	-34,62	F, T, Infrastr., HR

Key: HR = Human resources, P = policy, F = finance, Soc. = social, Cult. = culture, M = Market, Infrastr. = Infrastructure and T = technology

The analysis of the results of the first survey questionnaire was undertaken by the Human Sciences Research Council (HSRC) according to internationally accepted norms. The overall results of the first questionnaire are to be found in Appendix 5.

The following overall conclusions with regard to the six key variables supplied by the foresight project team are described below.

5.4.4 Characteristics of the top twenty statements

If one looks at the top twenty statements, it is clear that the statements cover most of the focus areas of the sector, i.e. customer linkages and supply chains, manufacturing's best operations/new processes, education and training. Areas like information and technology, robotics and smart/new materials featured relatively little in the top twenty statements.

5.4.5 Bottom ten statements

For comparison purposes, the bottom ten statements have also been included. One of the interesting characteristics of these statements is that they contain mainly futuristic technologies such as the use of biological structures in engineering design, fabrication and assembly with biological processes, designer proteins, enzymes and tissues, bio-catalysts, bio-assembly of new foods and bio-devices for computer equipment, bio-mimetic systems that synthesise proteins using natural and non-natural amino acids, and micro and nano-fabrication processes. While these technologies have not been considered important by the respondents for either wealth creation or improving quality of life in the short term, in the medium to long term, South Africa will need knowledge to improve decision making and niche developments.

5.4.6 Quality of life

The respondents seem to feel that education and training, capacity development and market-related issues are likely to make a major contribution towards improving quality of life.

5.4.7 Wealth creation

Most of the top twenty statements that are perceived as likely to contribute to wealth creation fall in the focal areas of customer linkages and supply chains, manufacturing's best operations/new processes and training and development. It is again apparent that because of the time frame for realisation being five to ten years, nano-technology and biotechnology, among other technologies, are not perceived as likely contributors to wealth creation in the short to medium term.

An overall analysis of the statements from the results of round two in terms of the five variables, viz. time frame for realisation, comparative standing, acquisition and key constraints, will be discussed.

5.4.8 Time frame for realisation

The respondents seem to feel that, for most statements, the likely time frame for realising most of the technologies reach a peak around six to 10 years, which is a medium- to long-term time frame. This is a general trend for all statements, including top twenty and bottom ten.

5.4.9 Comparative standing

For most statements, the respondents seem to feel that South Africa is ahead of Southern African and developing countries but behind developed countries. There is a slight variation on this trend for the top twenty statements. In the case of these, South Africa is not far behind the developing countries.

5.4.10 Acquisition

There seems to be two main preferred acquisition strategies, viz. engaging in joint ventures followed by developing in South Africa. If one looks at the top twenty statements, respondents seem to feel that developing in South Africa followed by engaging in joint ventures are the preferred strategies. For the bottom ten and in fact all statements the preferred strategy is engaging in joint ventures followed by developing in South Africa. It is also evident that for those technologies in which South Africa is behind the developed, developing and Southern African countries, the preferred acquisition strategy is through joint ventures followed by developing in South Africa. The case is different for the top twenty statements, where the order is reversed. These strategies could be useful in guiding the science and technology system in formulating its international agreements strategy.

5.4.11 Constraints

For all statements, the major constraints as perceived by the respondents seem to be human resource development technology and research and development infrastructure. For the top twenty statements, major constraints seem to be issues related to technology and policy. For the bottom ten, the major hurdles seem to be technology, human resource development and then R&D infrastructure. Market opportunities do not seem to be a major problem. This seems to suggest that the policy environment and socio-cultural issues are not perceived as major problems.

5.4.12 Analysis of the top 20 statements

With regard to the top 20 statements, nine statements were from the 'Linkages' topic, four from the 'Other' topic, four from the 'Manufacturing's best operation/New process' topic and one from the 'Education and training/Capacity development' topic. No statements from the 'Smart materials/New materials' topic or the 'IT and automation' topic were listed among the top 20 statements.

The top 20 statements could be interpreted in various ways, but the Working Group decided to look at the statements in a simple manner by asking the question, 'What are the respondents trying to tell us at an overarching level, even though they are responding to highly specific statements?'

The analysis of the top 20 statements clearly demonstrates that the respondents' key concerns relate to the issue of human resources and human resource development. The statement that received the highest joint-index rating was a statement that referred to the need for tertiary education institutions to transform in such a manner as to ensure the availability of high-quality and appropriate skills to support a strong manufacturing base (statement 54, ranking 1). This skills issue, in various guises, was also raised in the top 20 statements in relation to SMME skills transference and development (statement 7, ranking 5), leapfrogging by accessing foreign skills (statement 60, ranking 6), management skills and methodologies (statement 32, ranking 7; statement 55 ranking 9) and the need to develop industrial design skills associated with new products and new materials (statement 29, ranking 20). Human resource development at all levels and in its broadest interpretation is the key issue raised by Delphi respondents.

The second strong message that the top 20 statements communicates is that the South African manufacturing and materials sector is not viewed as internationally competitive, but that international markets will be crucial in the sector's contribution to wealth creation and quality of life. The respondents are clear that the sectors have to be assisted and they have to help themselves to increase their competitiveness and international market penetration. This issue raised itself in various forms. First, there is a high joint index related to the practical implementation of industry-specific clusters to assist in innovation and increased competitiveness (statement 4, ranking 3). Secondly, there are issues relating to government assistance to help with competitiveness (statement 58, ranking 4; statement 3, ranking 11). Thirdly, there is a strong realisation that competitiveness hinges on quality and time-to-market and that local manufacture must measure itself against international benchmarks in these two areas (statement 25, ranking 14; statement 61, ranking 15, statement 46, ranking 19). Finally, the issue of access to quality information about markets and suppliers and increased communication was noted as important for increased competitiveness (statement 1, ranking 10).

The final message that comes out of an analysis of the top 20 statements is that the respondents realise that they cannot compete internationally in all areas of manufacturing and materials development and application and that the sectors need to focus on areas in which a competitive and comparative advantage can be attained in a rapidly changing environment. The respondents identified raw material beneficiation (statement 8, ranking 8), mass customised products (statement 9, ranking 13) and small-batch manufacturing (statement 12, ranking 17) as the key niche markets to focus on.

Looking at these top 20 statements in more detail, the Working Group then began to analyse the key constraints identified.

The second step in the analysis of the top 20 statements was to look at the identified constraints with regard to each of the statements. This focus was adopted because of the underlying philosophy of the Foresight project, which aims to channel resources in an optimal manner with regard to the science and technology needs of a specific sector.

Across all 20 statements, human resources were identified as the most significant constraint in 45% of the statements and was listed as one of the top three key constraints in 90% of the statements. Finance was listed as one of the top three constraints in 85% of the statements, while R&D infrastructure only made the top three in 15% of the statements, with policy among the top three in 15% and social and cultural issues among the top three in 10%.

Technology was identified as the key constraint in four of the top 20 statements and was a top-three constraint in five of the remaining 16 statements. On average then, technology was a top-three constraint in 45% of the top 20 statements. The four statements in which technology was viewed as the largest constraint were statements 9, 11, 12 and 31, which coincide with the four top 20 statements addressing the issue of what manufacturing segment South African producers should be focusing on. This analysis supports a view that respondents to the questionnaire feel that they do not have the right technology or affordable technology in the markets in which they need to compete.

5.4.13 Analysis of the bottom 10 statements

Seventy per cent of the bottom 10 statements were from the topics 'New processes' and 'Smart materials/new materials'. These bottom 10 statements are dominated by statements regarding specific technologies such as biotechnology, semiconductors, biomimetic systems, micro- and nano-technologies and ceramic materials, all of which had been identified by the Working Group as the cutting-edge, key technologies with regard to the future of the manufacturing and materials sector worldwide.

This result is highly contradictory to the issue raised in the last paragraph of section 5.4.4. In the previous section it was reported that respondents identified technology as a constraint in 45% of the areas within which South African manufacturers and materials producers can operate internationally so as to improve the quality of life and wealth creation of South Africans.

There may be numerous explanations for such a highly relevant contradiction, and unfortunately the second-round questionnaire threw little light on the issue, and therefore all that can be reported is a list of possible explanations for such a contradiction:

- While technology is a constraint, the depth and enormity of the human resource constraint are considerable. The development of specific technologies cannot be viewed as directly translating into wealth creation and quality of life as a knock-on effect in the absence of the amelioration of the human resource constraint.

- The sample range of respondents who completed the questionnaire was skewed towards non-technical respondents, or respondents who had technical knowledge in relation to only one field of technical expertise.
- The technology-related statements were phrased in terms of access and development of technology, but may have failed to take into account the cost of acquiring or applying technology. Hence respondents may have identified technology as a constraint due to price, while the technology-specific questions in the topics 'Smart materials/new materials' and 'New processes' related to non-economic issues related to such technologies.
- Any combination of the above.

5.4.14 Comments by respondents

A number of useful comments were received from a large number of respondents and they were taken into consideration in the selection of and amendments to the wording of the statements for use in the Round 2 survey.

The most frequent comments related to human resource issues, with the impact of crime on the skills base and productivity and profitability being raised several times. A second recurring comment related to the need to change mindsets in relation to work, work practices, ethics, philosophies and relations as well as technology. A third and final common comment mentioned that certain statements were 'not relevant to South Africa'. The 'no relevancy comment' appeared in relation to such a large number of diverse statements that one could only conclude that there is in fact no strongly shared vision among the respondents in relation to where the manufacturing and materials sector needs to position itself or how it needs to reach this positioning.

5.4.15 Round 2 survey

A second-round survey of 23 questions was distributed to 130 potential respondents, 55 of whom returned completed surveys, giving a response rate of 42%. The questions selected for the second round included those questions that had achieved high rankings in the joint index, those that had high rankings in the wealth creation and quality of life indices separately and those statements that had received a disproportionately high number or interesting comments.

The general pattern that emerged from the second round was very similar to that identified in the first round. Significantly, however, one key differentiator emerged.

At a general level, technology-specific statements once again enjoyed the lowest ranking of the joint index, while issues related to market direction and environmental issues, such as human resources and finance, once again emerged as highly influential factors relating to a high joint-index score.

At a more specific level, a key differentiator between the first- and second-round responses was the greater value attributed to the focus of the manufacturing and materials sectors in the second round. Three of the top five statements in terms of the joint index addressed the need to operate in niche markets and to concentrate on downstream beneficiation.

5.4.16 Conclusion

The survey seems to be a useful tool in identifying emerging technologies and their potential applications in the economy and in providing societal solutions. There are a number of technologies that have been identified. They will be further explored in the next chapter.

The Working Group decided that Importance to South Africa would be the key variable used to analyse the survey results. A weighting process based on wealth creation and quality of life indices was used to develop a joint index and such an index was used to focus on key areas of importance to the manufacturing and materials sectors.

The group looked at the top 20 statements and the bottom 10 statements in more depth. They focused on those respondents who had indicated a high level of confidence in their responses. By definition, the reader could therefore assume that statements that received the lowest joint-index scores are in fact less important with regard to the impact of the manufacturing and materials sectors on South African wealth creation and quality of life. However, it will be shown that we believe this to be an untrue reflection of the Delphi findings.

Chapter 6: Recommendations

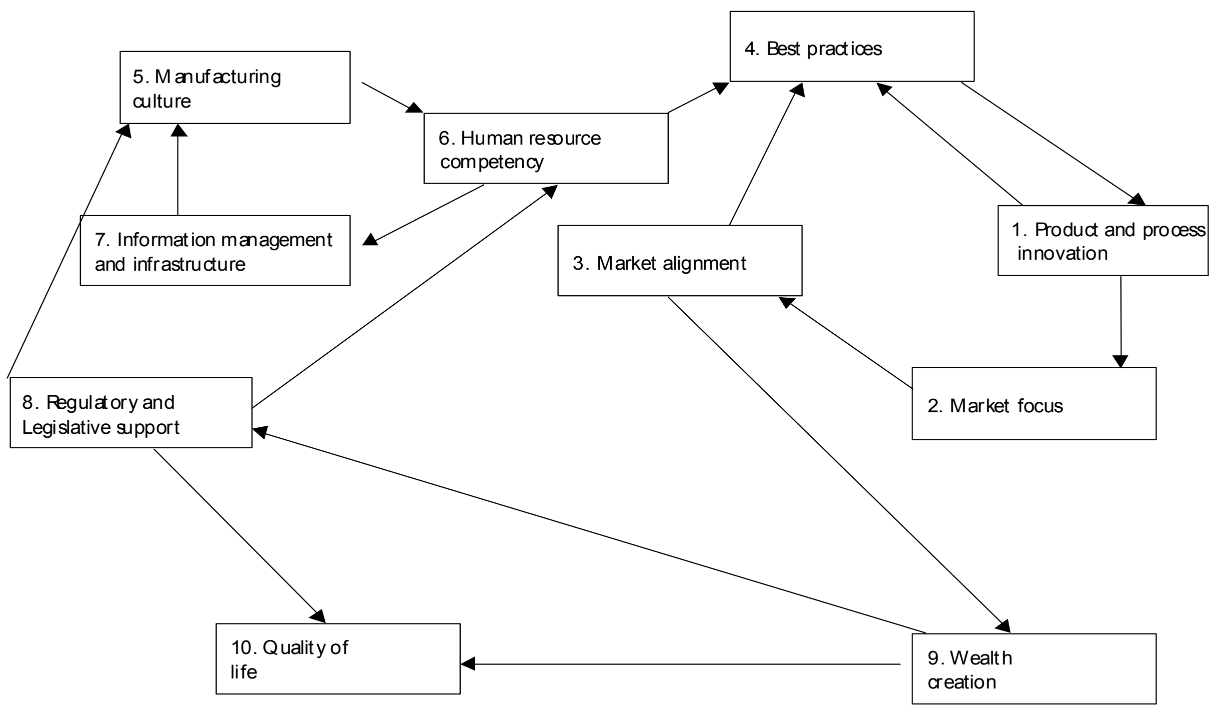
6.1 Introduction

The Manufacturing and Materials Foresight Team, reinforced by the conclusions of the Delphi study and the varied international reports, concluded that it would be a mistake to take a narrow, technologically focused perspective in formulating the recommendations. It was therefore essential to adopt a more holistic view. It is realised that certain of the recommendations will overlap with those of other Foresight teams but this will reinforce the findings and allow an integrated approach.

6.2 Enabling Model

In developing a methodological approach by which to capture the voluminous, complex and varied materials produced by the Foresight process in this sector, an interpretive structural model was developed that has been called 'the enabling model'. The enabling model captures the crucial elements of a series of nodes of influence, interdependency and feedback mechanisms of both a general environment and the specific technological environment of the manufacturing and materials sector. A rich tapestry of causality appears, upon which a basket of recommended activities can be justified, constructed and measured for success. In its complexity, the model highlights the necessity of a holistic approach to supporting the growth of the sector. It strongly suggests that ad hoc or partial implementation of the recommendations included in this chapter will result in suboptimal achievement of the desired outcomes.

ENABLING MODEL



Each rectangular box represents a 'node'. A node is similar to a theme. It is multifaceted and dynamic in nature and it is within each node that levers have been identified upon which activities (recommendations) can be focused that will result in change. The nodes in yellow (blocks 9 and 10) are the desired outcomes of the initiative to intervene in the manufacturing and materials sectors. The nodes in blue on the right (1, 2, 3 and 4) form a grouping of largely technologically intensive themes, while those on the left in green (5, 6, 7 and 8) are generally softer or more generally 'foundation' themes and issues. Connecting arrows indicate a range of relationships spanning direct causal relationships as well as lower-level influence or inter-relational linkages and feedback loops.

Although complex, the model portrays a virtuous circle whereby the application of resources necessary to improve the quality of life of South Africans through the development and growth of the manufacturing and materials sectors are explained. It requires such resources to flow not only to obvious, hard, tangible, directly related nodes, but simultaneously to nodes which at first appearance seem far removed and somewhat intangible.

6.3 Enabling capabilities

The remainder of this chapter looks at highly specific actions and activities that could be undertaken by both the public and private sectors that would address the needs identified within the model. The items placed in the boxes represent specific recommendations of where and how resources can be channeled so as to ensure that the manufacturing and materials sectors are well positioned to grow and develop in the future.

6.3.1 Product and process innovation

For South Africa to continue to grow a vibrant manufacturing and materials sector, two important drivers will become increasingly evident, viz. a focus on subsectors that are, or have the potential to be, world-class and continuous improvements of the technologies, products and processes associated with these value chains. Such focus will inevitably imply that some manufacturing subsectors will shrink.

While much technology will be acquired through importation, the philosophies of selective innovation, continuous improvement and value addition must be supported and grown to increase the competitive capabilities. More effort should be focused on appropriate product and process design to add to the benefits of high-quality and cheap energy availability and abundant raw materials.

It is recommended that resources be applied to making the environment for product and process innovation in South Africa more nurturing and supportive. Improving this environment for large and small players in both the manufacturing and materials sector requires looking at both human resource development and the development of support institutions and mechanisms.

South African product developers will need to stay abreast with or exceed requirements for clean production, waste minimisation, recycling and life cycle design management. To minimise the cost penalties of such needs, the structuring of South African subsectors into effective and mutually supportive clusters will be a key success factor.

The typical topics recommended for future development in the Foresight processes of the developed of Pacific-Rim countries were only given moderate importance, and in some cases full into the bottom 10, e.g. nano-technology and micro-fabrication. Likewise, the power of simulation technologies, which are acknowledged worldwide as a cost-effective component of new product and process development, was given limited prominence.

6.3.1.1 Key levers

- Transform tertiary education institutions to produce more engineers and scientists, including computer and design specialists, oriented in fields appropriate to the subsector clusters and niche industries. Development of multidisciplinary, team-based training capabilities.
- Develop, on an ongoing basis, expertise in technologies that allow mass customisation and reduce time-to market.
- Develop an incubator system that applies international standards to the stimulation and support of start-up companies built around innovative products and processes.
- Develop local venture-capital industry.
- Research and develop an approach to waste management and recycling for all key value chains.
- Establish and support international exchange programmes with overseas technology institutions related to selected value chains or niches.
- Develop an analysis framework to provide ongoing decision support on 'next generation' value chains to extend the current 'short-termism' seen in the survey.
- Pre-competitive research and development support is a supply-side incentive for well organised industry subsectors and value chains. Cross linkages between the 'materials-oriented' value chains, e.g. stainless steel, and system industries, e.g. automotive, should be encouraged and promoted.

6.3.1.2 Key technologies

Key technologies that will underpin the above are as follows:

(a) Shorter term

- Technologies to promote the existing beneficiation value chain in South Africa
  - continued process and product development of basic materials
    - alloy development
    - polymer development, especially through indigenous coal-based technologies
    - indigenous biomaterials, e.g. natural fibres
    - further processing of precious metals, e.g. Platinum group

  - downstream product technologies for metal products, e.g. stainless steel, aluminium, precious metals
    - near-shape processing technologies
    - deeper knowledge and research in optimised technologies for metal forming and joining
    - design and integration of materials in optimum products

  - downstream product technologies for polymer products
    - advanced moulding technologies
    - computer-based analysis to support product and process design
    - life-cycle management

- Simulation, modeling and visualisation
  - computer-based technologies to support
    - product design optimisation (including virtual prototyping)
    - process design and optimisation (including plant operation and layout)
    - tooling design
  - design/product data interchange in value chains

- Development of more energy-conserving processes for materials beneficiation and application

(b) Longer term

- Development of capabilities to implement 'miniaturisation' and 'smartness' into products
  - increase precision manufacturing and near-shape technologies
  - direct manufacturing technology ('free-form manufacturing without tooling')
  - integrated sensor/actuator technologies into products

- Development of customised materials designed for specific product needs
  — improved methodologies for materials design and development
  — designing with environmentally-friendly/recyclable materials

- Development of a manufacturing industry aimed at niche 'information-age' products built from local strengths, despite having essentially missed the semi-conductor/active materials era of the 1970-1990s

- Application of biotechnology development methods to natural fibre optimisation for structural composite applications.

6.3.1.3 Comment on smart materials/new materials

Modern products incorporate more 'smartness' or active materials and devices, an area in which South Africa is underdeveloped owing to 'some degree of isolation'. The response to the survey on smart/new materials was cautious or negative in the short term compared to the response on other, more traditional commodity or beneficiation industries, which were seen as urgent and important priorities.

For South Africa to move into more value-added products and systems in the longer term, attention to the application of smart materials and devices will become increasingly important. Unless addressed by selecting relevant and niche areas for development, the gap between current South African manufacturing industries and the high-value-added markets will increase.

Specific encouragement should be given to the linkage of natural science research (i.e. physics, chemistry and biotechnology) and technological research in our tertiary institutions to the field of smart and new materials relevant to South Africa. Special focus areas in the Innovation Fund should be maintained and mechanisms to gather industry needs on an ongoing basis should be supported.

6.3.2 Market focus

South Africa's industrial history remains a combination of world-class minerals/raw materials extraction based on a primary process industry and a broad range of discrete product manufacturing sectors originally focused on internal needs and now facing the harsh reality of globalisation. This latter trend has highlighted the worldwide need to optimise supply chains and customer/market linkages. Not surprisingly, therefore, this theme received a strong reaction and importance in the survey, with nine out of 13 statements occurring in the top 20 importance ratings.

Strong support is provided for the need, over the next 10 years, to implement specific industrial clusters that will result in an ability to innovate and compete in world markets. Added to this is the emphasis that South Africa's manufacturing production will, in the coming decade, still be characterised by raw material beneficiation but with improved value-chain management and more innovation in design and production technology. Furthermore, the survey stressed the need for South African manufacturers to be more focused and to become world leaders in niche markets in a limited number of products.

Although some respondents highlighted the historically poor track record in South Africa of collaboration and sharing, there is a need to rectify this situation. Comprehensive networks must be developed, including the increasingly important SMME sector, and they must be supported by data networks and information. In this domain, however, the constraints are less technological than financial, with apparent concerns on the availability of adequate human resource capabilities.

With regard to longer-term trends with a strong technology requirement, comes, the appreciated importance of mass customisation of products. This, together with the potential to develop South Africa's small-batch manufacturing capabilities, has potential for impacted competitiveness. In both fields, however, there are perceived technological market and human-resource constraints, but the linkage with R&D is not strongly indicated. The acquisition of the required technologies/capabilities is not based on importation, but has a strong component of local development and joint venturing.

Although in the past, many sectors of the manufacturing industry have been protected from tariff barriers, the strong response of the survey was that such policies would be detrimental to a globally active industry.

The greater focus on downstream products, even if based in the short to medium term on beneficiation of South African materials, will require a greatly improved linkage with international markets. The trends to use the Internet, e-commerce and IT-based marketing will become essential if SA is to stay aligned with market trends.

This set of recommendations therefore relates to the needs of local manufacturers, increasingly in well-aligned subsector value-adding supply chains. While the focus will predominantly be on export orientation, requiring greater knowledge and access to developments in the international market, there will be a need simultaneously to continue to grow low and regional markets and to develop a national sense of pride in local production.

6.3.2.1 Key levers

- Provide information and financial support for industrialists to attend international industry-specific exhibitions and conferences.
- Develop 'knowledge engines' with regard to key sectors of our manufacturing industry, continuously analysing trends and stimulating relevant, pre-competitive research and development.
- Understand environmental trends in worldwide markets to assess the impact on the South African industry.
- A 'Local is lekker' campaign for locally manufactured goods and use it to publicise success stories.
- Use and display items made by our local industry at every opportunity.
- Development for growing subsectors, or those being stimulated as per the German, Taiwanese or Singaporean models.

6.3.2.2 Key technologies

- Data networks and other information technology systems.
- Implementation and appropriate adaptation of technologies enhancing market linkages and collaboration, e.g. teleconferencing.
- Technologies to intelligently handle information that allow industries to cope better with the increasing volume of data.
- Environmental technologies to ensure product/process compatibility with markets and foreign government regulations.

6.3.3 Market alignment

South African manufacturing industries, once focused on the export market, will become selective in the range of products being produced. In this regard, the specific requirements of these user markets will become prime drivers for product development, quality, delivery, etc.

The recommendation with regard to market alignment is that once 'winning sectors' have been identified, private and public resources should flow to these sectors on a preferential basis, ensuring that market competitiveness is not compromised by the spreading of resources and support across a variety of fields. Such processes of selection can be supported by the ability of subsectors to align and jointly structure activities, e.g. export councils, trading companies and cooperative development initiatives. Attractiveness to foreign investment and joint ventures should also be indicative of increasingly competitive sectors.

6.3.3.1 Key levers

- The creation and funding of strategically planned, industry-specific support centres.

- Research and development mechanisms to help local industry to decrease time-to-market., e.g. Concurrent engineering approaches.
- Focus on R&D in technologies needed specifically in sectors to increase value-added, downstream manufacturing in the key beneficiation and materials chains.
- Help companies to achieve ISO9000, ISO14000, QS9000, VDA6 and other necessary, internationally recognised quality-control standards.
- Understand fully the environmental issues associated with the focus subsectors.
- Give information and financial support to international trade shows and other exhibitions.
- Support alignment of tertiary education teaching and research programmes to national priority sectors.

6.3.3.2 Key technologies

(a) Technologies for the short term

- Technologies that promote the ability of our industry to rapidly develop value-added products, well designed to international standards and within global time scales:
  - concurrent engineering techniques
  - electronic data interchange
  - CAD, CAM and CAE
  - computer simulation of design and product production
  - rapid prototyping and tooling development
- In the basic materials arena, technologies to allow new/adapted materials to meet customer requirements.

(b) Technologies for the longer term (8 years+)

- On-line market/customer information on products
- Development of technologies to respond to issues of 'mass customisation':
  - adaptive or flexible manufacturing technologies
  - optimisation of small-batch production
- Enterprise simulation/cost modeling
- Meeting demands of environmental requirements of international customers:
  - low-waste processes
  - energy conservation
  - product reclamation and recycling
  - life-cycle product management and costing.

6.2.4 Best practices

Internationally, significant development has occurred in the management and operation of manufacturing enterprises. Although some industries in South Africa have rapidly assimilated these practices, this will be an ongoing process of continuous learning and implementation. To ensure the adoption of best practices in the local industry, it is recommended that steps be taken to transfer and diffuse such knowledge in a manner optimised for the skills levels of the local workforce.

Best practices that are associated with the 'reconfigurable enterprise' concept involving rapid new-product development and production ramp-up as well as flexibility with regard to small-batch production will need consideration. With South Africa's tradition of production for local market conditions, such developments could enable SA to leapfrog beyond countries that have only focused on economies of scale. Local best practice should be assessed and developed.

6.2.4.1 Key levers

- Develop and implement policy to ensure quality-control mechanisms that are internationally accepted, are created and adhered to.
- Develop industry/sector norms and standards reflecting best-practice operations to provide a measurement basis for companies.
- Organise international conferences/workshops for CEOs to discuss business models, strategy technology, alliances and partnerships.
- Development of best-practice principles for sector value chains.

6.2.4.2 Key technologies

- Development of computer-based training methods to channel international best practice into the factory.
  - — virtual reality training methods.
- Re-assess the human/machine interface for optimised local application of best-practice principles.
- Flexible/lean manufacturing techniques.
- Machine vision.

6.2.5 Manufacturing culture

Crucial to the positioning of the manufacturing and materials sector in the next millennium will be the development of a new and more competitive manufacturing culture. It is suggested that this responsibility lies predominantly with the private-sector industries themselves, but we recommend that they create a network with public and educational stakeholders to ensure that such a culture is inculcated at all levels.

- Redesign cluster process — clusters to be responsible for developing web-based workbooks, best-practices forums, information dissemination, 'chat rooms,' etc.
- Establish formal, industry-specific golden triangles (industry-universities-government) as per Carolina State (US) or Orange County (US) model.

- Utilisation of global infomediaries to be disseminated and encouraged in industry.

6.2.5.1 Key technologies

- Information technology and other infomediaries technologies.
- Computer/Internet-based continuing education.

6.2.6 Human resource competency

Education and training/capacity development

The global study has highlighted the fact that modern manufacturing requires increasing levels of skill for management and workforce. It will no longer be adequate to use cheap, unskilled labour as a competitive factor in the coming decades. Therefore, the survey gave high importance to the education and training/capacity development field as a determinant of both creation of wealth and quality of life improvement.

Overall, the level of confidence of respondents indicated in the Delphi survey on this topic was one of the highest, confirming the fact that skills and education represent a topic of current concern in the manufacturing and materials industries.

Highest of all the responses was the transformation of educational institutions (universities and technikons) to ensure high-quality, appropriate skills development to support a strong manufacturing base. The additional comments highlighted the need for a strategy for training to commence before tertiary levels and the committed will of the nation to impact on technological education, but with a good balance of vocational and academic training. Few saw this as a field in which importation is the answer and]they felt instead?] that concerted local effort is needed, both in development and appropriate joint ventures. Less traditional training methods based on multimedia, computer-based training and virtual technology simulation showed a stronger element of importation of technology, but remain important approaches. Multiskilling and team-based working patterns are also predicted to play an important role.

The ability to succeed in this domain will rely on a combination of appropriate legislature and policy development by government and the strengthening of public/private sector relationships so that international transfers may be maximised and opportunities may be provided for the country to leapfrog ahead.

Confirmation was also provided of the need to use and adhere to international quality and environmental standards. Thus, such items need to become an integral part of capacity development in the short term, given that quality is now seen as an essential entry factor to operate in the global manufacturing arena.

It is recommended that South Africa urgently increase its human-resource competency in respect of all levels of the labour force.

- Develop more strongly industry-focused, 'tertiary education institutions' with integrated curricula, e.g. manufacturing universities/strong departments, software polytechnics (including business schools and 'soft-science' departments), software polytechnics.
- Focus on developing high-tech engineers and designers who understand modern manufacturing and concurrent practices.
- Immigration policy.
- Improve quality of management.
- Utilise virtual-technology simulation and other computer-based training methods to channel international best practice into the factory.

6.2.6.1 Key levers

- Develop more strongly industry-focused 'tertiary education institutions' with integrated curricula, e.g. a manufacturing university or school, which should link up with business schools and 'soft-science' departments.
  - future manufacturing industries will need people from different disciplines able to work in teams and in a concurrent mode: such an emphasis should be part of the training
- Develop technologies that will allow continuing education at all levels in the work environment
  - tele-education
  - computer-based education
  - virtual reality training
- Review of key skills needs and influence of immigration policy
- Ensure opportunity for manufacturing management education
- Focus on developing high-technology-oriented engineers and designers who understand modern manufacturing and concurrent practices.

6.2.6.2 Key technologies

- Develop distance-learning technologies
- Develop new cross-disciplinary research orientations to better address needs of manufacturing industries of the future.

6.2.7 Information management and infrastructure

The survey acknowledges the importance of information technology, e.g. in e-commerce, knowledge management and in production environment, but only in the longer term.

The Manufacturing and Materials Foresight Team, however, believes that the impact of IT on the whole value chain will be a key driver of the coming decade. Underestimation of this impact will reduce the ability to interface with the market and manage operations effectively.

6.2.7.1 Key levers

Several technologies that emerged as important in this sector will be analysed in more detail in the ICT Working Group report, but for the purposes of the manufacturing and materials sectors, several IT-related technologies were identified as needing to be highlighted. High on this list were e-commerce, knowledge-based engineering and automated systems that all of which were viewed as crucial to the development of the sectors.

- Monitoring and control systems for the production cycle.
- Enterprise management systems (ERP, etc.).
- Electronic data interchange between enterprises in SA and internationally.
- Logistics and supply-chain management.
- Simulation and modelling across a broad spectrum of activities.
- Human/machine interface optimisation.
- Facilitate increased utilisation of market information and e-commerce.

6.2.8 Regulatory and legislative support

It is recommended that the legislative and regulatory framework be re-designed to decrease the costs of R&D and innovation in the manufacturing and materials sector. Soft-support and legal-protection mechanisms must also be put in place.

- Tax rebates and depreciation to decrease cost of R&D and R&D implementation.
- Tax rebates and depreciation allowance to upgrade capital stock.
- Develop institutions to hand hold for capital upgrades.
- Expand IPP commitment requirements to include assistance to venture capital, incubators, R&D and R&D institutions.
- Re-look at IPR system with a view to decreasing complexity and cost while increasing effectiveness and efficiency.