DEPARTMENT OF TRADE & INDUSTRY:

Benchmarking of Technology

Trends and Technology Developments

A report prepared by

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and

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EXECUTIVE SUMMARY

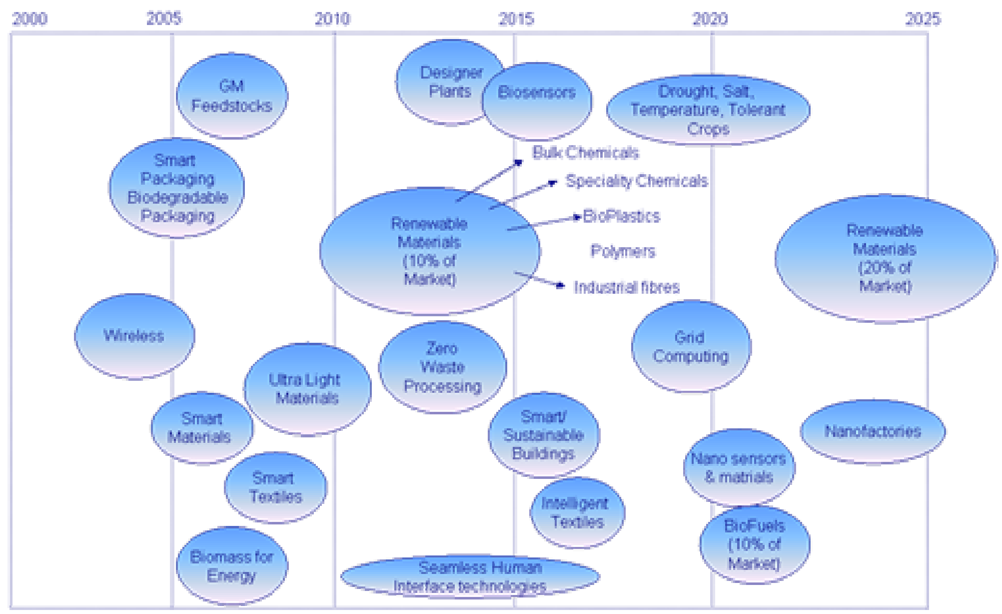
South Africa has over the past decades developed a vast technological base. This base spans many organisations, a considerable number of which reside within both public and private companies classified within the industrial sectors in South Africa. As South Africa has the opportunity to compete internationally, there exists an enormous potential to exploit and leverage selected technologies, in promoting business growth through exports thereby earning foreign currency. It is also essential that South Africa implement its technology strategy so that technology is applied to the maximum benefit of the entire nation and that strengths are exploited to their extreme so that the future workforce can benefit as well.

One of the needs that were identified as part of the process of supporting industry sectors is the need to have in-depth understanding on technological developments globally. Such understanding and the dissemination of such information is seen to be key to ensuring the long term competitiveness of South Africa's industries in the global context.

Summaries of the findings are set out in the following pages. The summaries highlight the key technologies influencing the development of the sectors. The study also reviews the support mechanisms applied by various governments to improve the ability of countries to benefit from whatever technological developments may occur in the time horizon to 2015. In order to understand the full context of the emerging trends and critical technologies the reader should refer to each specific chapter.

A view of the new waves of technology on the global front provides an essential context to understanding technology opportunities and threats within any specific sector. Examples of the major technologies are indicated on a timeline in figure 1:

High Impact Technology Waves



A per sector summary follows, indicating the most important technologies expected to have a strong potential to influence national competitiveness, employment and quality of life.

THE ICT SECTOR

The future global ICT landscape can be summarised as encompassing very unobtrusive hardware, a seamless mobile/fixed communications infrastructure, dynamic and massively distributed device networks, natural feeling human interfaces in a secure ubiquitous computing environment.

Three main technology groups will dominate the future ICT landscape

- the society will be connected and there is a need for mobile technologies which include wireless, wearables, Wi-Fi, ultra-wide band, smart phones and location-based services;
- there will be an increase in smart networked objects which include technologies like RFID, MEMS, smart dust, digital ink and embedded computing) and
- there will be semantic connectivity including technologies like Semantic Web, XBRL, automatic tagging, affinity profiles and information extraction.

Taking the above into consideration a condensed list of emerging technologies was made. It is of the notion from various industry experts that these emerging global technologies are very important for the growth and continued development of the sector within South Africa. The technologies are listed below:

- Mobile technologies and devices
- Wireless network technologies
- Human Language Technologies
- Open Source Software
- Telemedicine
- Geomatics
- Manufacturing Technologies (Robotics/Artificial Intelligence)
- Grid computing
- RFID (Radio Frequency Identification)

THE TOURISM SECTOR

The WTTC has predicted that the tourism industry will continue to grow steadily through the years. According to WTO South Africa was ranked as 25th top tourism destination in 2000.

For South Africa to benefit from the tourism sector to its maximum it requires economic growth and sustainability. A clean, safe and healthy environment is necessary for sustainable tourism, in creating growth marketing the country to the rest of the world is very important as well as participation from the broader population, constant development of the product i.e. South Africa, enable the provision of good services and a secure tourism destination.

The technologies that can support these requirements and assist in ensuring sustainability and growth of the sector are ICT, environmental technologies (which include fuel efficiency, cleaner production processes), renewable resources and cultural heritage technologies. An important fact to keep in mind is that ICT is extremely prominent within the sector and is slowly changing the tourism environment as we know it today; obviously there is an understanding that the industry cannot be wholly driven by ICT but it does allow more flexibility and accessibility within travel and tourism.

ICT is changing the current tourism environment and it allows more flexibility and accessibility within this particular industry. Although the tourism sector is not wholly driven by ICT, it is a prominent enabling technology. The tourism industry needs to use technology to improve productivity in reaching a broad and diverse customer base. To do this, it must be flexible and responsive to rapid change as well as be stable and responsible to its existing customer base and suppliers.

It will be imperative to have strong relationships with customers and to use technology for frequent, interactive communication and targeted benefits.

THE CULTURAL SECTOR

Cultural Industries is a large global industry and has a huge potential in job creation and also offers an opportunity to develop less favoured regions. New and original industries emerge not necessarily from the use of new technologies, but from creativity, skills or traditional materials. This makes crafts and tourism related industries a springboard for development. Internationally, the cultural industries are recognised as having significant economic benefits. Past figures of culture sector’s contribution to GDP and employment illustrate the economic and job-creation potential of cultural industries.

Although cultural industries are an important part of the economy there are constraints causing a backlog, the major concerns are that the sector does not have appropriate training and skill development, urbanisation is causing a lack of transfer of traditional skills within the families, there is a lack of knowledge management, research and development is literally very minimal. Other constraints include access to raw materials, skills development, finance, support services and problems within areas relating to marketing, infrastructure as well as production

The most important technologies which are an incremental part of developing the sector is enabling communication technologies, technologies which improve the product and the technologies that provide marketing to the end-consumer.

An important factor in the development of the sector is the quality of market information and of industry analysis. Crafts are a complex and fragmented sector which is difficult to define and classify. Improved knowledge of current and potential markets and of more effective ways to target them should greatly enhance the growth potential of the industry. This quality of market information will be able to be accessed through having entrance to technology platforms like mobile and wireless technologies as well as the internet.

THE AGRO-PROCESSING SECTOR

The convergence of several key industry trends has accelerated the pace of change in today's agro-processing industry. In response to declining profits, producers are developing new products with higher margins and functions, new uses for old products and waste streams, and incorporating cutting edge production technologies. Meanwhile, customer consumption habits are shifting and demanding new products such as organic produce and functional foods. On top of this, outside stakeholders, including government, are demanding an improvement to the environmental performance of the agriculture industry.

Food processing in all its various forms brings immeasurable benefits in terms of availability, shelf-life, and safety. This is important for safely feeding nations in which spoilage and other forms of damage and deterioration pose serious problems. Moreover, since processed products of all types retain their nutrients for an extended time, they are often the best way to provide countries experiencing chronic food shortages with an adequate supply of nutritious products.

The following list summarises the important research and technological developments for the agro-processing sector:

- Real-time detection of microorganisms in food, using a variety of methods
- Sensors for online, real-time control and monitoring of food processing
- DNA/ RNA chip technologies to speed detection and analysis of toxins in foods
- Food pathogen sensors as small as dust
- Separation modules that force molecules into confined environments
- Real-time detection systems for verification and validation of intervention technologies used in Hazard Analysis and Critical Control Points (HACCP) systems
- Better understanding of tolerable intake levels for nutraceuticals/ dietary supplement components
- Techniques to inactivate microorganisms to yield safer foods with extended shelf lives
- Standardized edible food packaging films
- Biological (e.g., bacteriocins) and chemical inhibitors to prevent or slow growth of pathogens in food
- Technologies for food traceability

Amongst the most critical for South Africa are technologies to enable food traceability and technologies to minimize food wastage. Food traceability is a critical factor for global players as indicated by renewed attention to the issue by the European Union. Food wastages can be reduced through application ICT and process solutions throughout the supply chain, and by application of processing and packaging technologies to increase shelf life of products.

THE BIOTECHNOLOGY SECTOR

To date, South Africa has only a very small bioeconomy, although biotechnologies are widely used in a number of industrial sectors including food and beverage, and waste water treatment. The emphasis in South Africa is still at the R&D level, the application of a new set of technologies and the application of the technology tools by defined sectors.

Most important areas for further development include the following:

- **Recombinant Therapeutic Products**. Includes the recombinant production of therapeutics, which could be proteins, metabolites, or other small molecules, and the production of generic medicines. It enables the modification of microorganisms, animals and plants so that they produce medically useful substances, for example human proteins

- **Vaccines.** Development, manufacture and clinical testing of novel human vaccines against important infectious diseases such as HIV/AIDS, TB, malaria, rotavirus and diarrhoea.

- **Diagnostics.** Includes the instruments and reagents used for the screening, diagnosis and monitoring or prognosis of a disease by laboratory methodologies. These products may be used in hospitals and private laboratories, in physician's rooms and other point-of-care sites (out-patient clinics, casualties and intensive care units) as well as in home testing (diabetic glucose monitoring and pregnancy tests).

- **Commodity** Chemicals from Biomass. Feedstock chemicals serve as the basic building blocks in the synthesis of other chemicals, ranging from small molecules to plastics and rubber, or as solvents in a variety of industrial processes

- **Energy from Renewable Resources**. Alternative and/or renewable raw materials for the production of commercially important products such as plant biomass.

- **Biocatalysts** Industrial biotechnology companies look for biocatalysts with industrial value in the natural environment; improve the biocatalysts to meet very specific needs, using the techniques described below; and manufacture them in commercial quantities using fermentation systems similar to those that produce human therapeutic proteins or bulk yeast for the brewing and baking industries. In some cases, genetically altered microbes (bacteria, yeast, etc.) carry out the fermentation. In other cases, either naturally occurring microbes or microbes genetically modified with other techniques are the production organism.

Those sub-technologies common to all the focus areas, and generally considered to be of highest priority were found to be; functional genomics (with specific focus on gene expression analysis); high throughput screening (based on substantial bioassay development); bioinformatics (including biological data management and extraction); biosafety; and high throughput genome sequencing.

The priority technologies span the various stages of new product and service development, extending from discovery to manufacture, but with more emphasis on discovery.

THE CHEMICALS SECTOR

This heterogeneous sector is expecting somewhat different development paths depending on the sub sector. While specialty chemicals most likely will be significantly influenced by nanoscience and biotechnology in the future, the changes envisaged for basic chemicals (i.e. petrochemicals, bulk polymers and fertilisers) are thought to be more based on evolutionary development. Disruptive innovations are difficult in basic chemicals industry since they have to fit with existing infrastructure of both the industry and society.

In this evolutionary development, every traditional category of materials will be important since the trend is the growing of cross-linkages between them. The clear trend globally of convergence of different strands of science and technology and knowledge transfer between different materials and scientific fields will grow even stronger.

Most important emerging technologies on the global landscape include materials technology, biotechnology and nano-technology. Examples of some of the important emerging technologies include:

- Mass-synthesizing technology for fullerene carbon compounds.
- Photo-catalysts for organic synthetic processes.
- Artificial high performance catalysis for manufacture of chemicals near normal temperatures and pressures.
- Organic ferro-magnetic materials.
- Bio-plastics, Polymer conductors.
- Selective catalytic cracking technology for naphtha.
- Direct synthesis of phenol from benzene.
- Combinatorial chemistry.
- Chiral chemistry and asymmetric catalysis.
- Advanced enzyme evolution techniques.

- RNA catalysis.
- Biomimetic catalysis.
- Advanced zeolite catalysis.
- Polymer functionalization.

The recent AMTS project identified key areas that should be further developed to capatilise on the industry's strengths and market demand.

The CSTT has identified a number of such interventions that are considered to have a major potential benefit for the local industry, including:

- Development of a new industry based on the extraction of minerals from coal ash and low-value slag.
- Extension of NECSA's expertise in fluorine generation and use in order to generate a range of fluorinated organic chemical intermediates.
- Development of a new range of performance chemicals that will improve the recovery of minerals in the mining sector (such as polymer used in solvent extraction processes).
- Establishment of a new technology platform that will develop technologies to decrease economies of scale for chemical plants and hence enable smaller production facilities to compete against the mega plants.
- Support for existing development efforts in low-cost diagnostics, aroma chemicals production, development of biodegradable and high-performance polymers, bio-diesel and products from alpha-olefins.
- A major initiative to build South Africa's first generic pharmaceutical actives plant in order to meet future demand for antibiotics and/or anti-retrovirals.
- A highly integrated strategy to fully develop South Africa's ability to add maximum value to its natural products and unique biodiversity.

Linkages between these areas and global emerging technologies should be drawn. These should be used as a platform to further develop South Africa's capabilities into areas of importance as indicated by international experts.

THE AEROSPACE SECTOR

The Aerospace industry will always be a driver for technological and economic growth, and will always be seen as an incubator of critical and pervasive technologies

The South African Aerospace industry currently has vast capabilities as a result of the strategic funding used for military purposes over the last forty years. The South African industry has the ability to design and manufacture tier 1 complete systems like unmanned aerial vehicles. There also exist pockets of niche expertise in various Aerospace disciplines and sub sector activities. There is no doubt that the Aerospace industry can be a vital instrument in achieving the goal of making South Africa a leader of innovation and emerging technologies.

In terms of this study, six technologies were highlighted as being critically important for the continuous development and growth of the Aerospace sector. These are:

- Development of composite materials
- Development of hyper aero-thermodynamics
- Development of Sensor usage
- Health and Usage Monitoring systems
- Noise Abatement
- Improved manufacturing processes

THE CLOTHING AND TEXTILE SECTOR

This sector has undergone rapid changes over the recent past. Until the 90's the sector was dominated by the Fashion industry but with trade liberalisation, the niche markets held by certain leading producers such as the US and western European countries (Italy and France) have been lost to cheaper exporters such as China and India.

Furthermore with technological advancement in the Textiles Industry towards value-added natural fibres and synthetic fibres the requirements of higher skilled workers increased. The industry in the established textile producing countries struggled to adapt to this new demand leading to a decrease in their output.

One on the most significant factors contributing to the shift in demand is that of technological development more broadly – other sectors such as aeronautics and automotive have created new demands on the textiles sector, such as sensory fabrics for seating comfort, resin-reinforced fabrics to replace metal components which creates lighter weight vehicles. The growing demand for intelligent and high performance textiles has created new opportunities in the Textiles Sector but industry in the established markets have been slow to respond to this demand.

South Africa is at a comparative advantage in the natural fibres segment of the Clothing & Textile Sector.

Simply put value addition of natural fibres is the process by which natural fibres are augmented to produce superior quality. Specifically, the technology components include:

Testing systems for foreign fibres in Mohair and wool: These technologies assist with the identification of weaknesses in fibres, enabling categorisation and grading according to export standards. In the long term these systems identify genomic features that are predisposed to low or high durability.

Yarn formation; long and short staple systems: Given the diversification of products from Mohair, yarn demands in the global market are varied. Providing global importers with a variety of yarn products creates greater responsiveness to market trends in Mohair (and cotton to a limited degree) and therefore a competitive advantage.

Dying and finishing technologies: These technologies also focus on beneficiating raw materials and similarly provide for greater diversity in South Africa's natural fibre offerings. Particularly advanced, are those products benefiting from application of easy-care substances for easier handling and care such as crease-resistance, shrink resistance and colour consolidation.

A growing market globally is the market from plant fibres. Hemp, flax and similar products are in abundance in South Africa. Processing of plant fibres thus becomes a critical niche market that South Africa is in an opportunistic position to exploit.

THE METALS AND MINERALS SECTOR

The metals and minerals sector is mature world wide with little major innovation taking place. The current technology trends are towards incremental improvements in the various value chain processes. The purpose of innovation, especially in the heavy metals sector, is to ensure business sustainability within the commoditised market and emphasis is placed on aspects such as the improved use of gravel as a form of ore, the improved extraction of lower grade ore by developing improved reduction and extraction techniques and the more efficient use of energy.

There is, however, more innovative work being done in the light metals sector, specifically aluminium, magnesium, titanium and the development of alloys. Down stream possibilities of these metals are large enough to warrant significant levels of research and development. One of the major focus areas of this trend is the development of a cheaper, continuous extraction processes for magnesium and titanium.

THE AUTOMOTIVE SECTOR

Technology and innovation play a vital role in the automotive industry. This is illustrated by the fact that there are more computers aboard a car today than was aboard the first spaceship. A new car has an estimated 10-15 on-board computers, operating the engine, radio, brakes, transmission, steering systems and other components.

In terms of this study, four technologies were highlighted as being critically important for the continuous development and growth of the automotive sector.

These are:

- Development of lightweight materials
- Development of alternate fuels e.g. fuel cell technology
- Sensors, electronics and telematics
- Improved design and manufacturing processes

Emerging technologies are revolutionising the automotive industry, transforming the roles of cars from mere modes of transportation to highly sophisticated entities that respond to various stimuli in a logical, intelligent fashion.

Globally the automotive industry is driven by two key factors: the regulatory environment in which the products are manufactured and operated, and the customer.

Developments over recent times have created a paradigm shift to a knowledge-based society in which human activity is increasingly focused on ideas, an area in which considerable progress remains to be made.

This report presents a vision of some of the most probable key technologies impacting on South Africa by the year 2010.

The predominant focus is therefore on emerging technological developments. However, it should be borne in mind by readers that many existing technologies will still be of critical importance ten years from now and merit the same analysis carried out in this study.

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1 BACKGROUND

1.1 Competing in the Global Economy

Dramatic moments in the history of industrial change have always been characterised by the successful exploitation of new ideas and the achievements of innovators.

Innovation has driven economic progress, from the invention of the spinning jenny that transformed the textile industry during the 18th century, to the harnessing of electricity and the development of mass production. More recently, semi-conductors, the internet and mobile technology have revolutionised business performance and the economic potential of nations.

Today, there are three reasons why innovation is even more urgent for companies and countries:

1. Trade liberalisation and a rapid fall in communication and transport costs mean that the South Africa must increasingly compete against countries with lower labour costs and well-educated labour forces.

2. Technology and scientific understanding are changing our world faster than ever before. Developments in Information and Communications Technologies (ICT), new materials, biotechnology, new fuels and nanotechnology are unleashing new waves of innovation, and creating many opportunities for entrepreneurial businesses to gain competitive advantage; and

3. Global communications, the 24 hours, 7 days of the week media phenomenon of the 21st century, mean that consumer tastes are also changing faster, as new fashions, ideas and products spread across the world almost instantaneously.

These developments are occurring at a speed and on a scale never seen before.

In the past, many businesses have prospered even when selling in low value markets, but today industry faces a new challenge: how to raise its rate of innovation?

We find that the competitiveness agenda facing leaders in Government and business reflects the challenges of moving from a location competing on relatively low costs of doing business to a location competing on unique value and innovation.

This transition requires investments in different elements of the business environment, upgrading of company strategies, and the creation and strengthening of new types of institutions.

1.2 Why Innovation is Important

We define innovation as "the successful exploitation of new ideas". Often it involves new technologies or technological applications. Innovation matters because it can deliver better products and services, new, cleaner and more efficient production processes and improved business models.

For consumers, innovation means higher quality and better value goods, more efficient services (both private and public) and higher standards of living.

For businesses, innovation means sustained or improved growth. The innovative company or organization delivers higher profits for its owners and investors. For employees, innovation means new and more interesting work, better skills and higher wages. Equally, an absence of innovation can lead to business stagnation and a loss of jobs.

For the economy as a whole innovation is the key to higher productivity and greater prosperity for all. Innovation will also be essential for meeting the environmental challenges of the future.

We need to find new ways to break the link between economic growth and resource depletion and environmental degradation.

It is important to every sector of the economy, in both manufacturing and services. To be globally competitive in modern manufacturing South Africa will need to innovate strongly, creating new high-tech manufacturing industries such as biotechnology and upgrading traditional sectors such as steel and textiles. Advances in science and technology offer many opportunities

2 INTRODUCTION

South Africa has over the past decades developed a vast technological base. This base spans many organisations, a considerable number of which reside within both public and private companies classified within the industrial sectors in South Africa. As South Africa has the opportunity to compete internationally, there exists an enormous potential to exploit and leverage selected technologies, in promoting business growth through exports thereby earning foreign currency. It is also essential that South Africa implement its technology strategy so that technology is applied to the maximum benefit of the entire nation and our strengths exploited to their extreme so that the future workforce can benefit as well

The Innovation and Technology unit (I&T) of the Enterprises and Industry Development Division (EIDD), through its Technology Linkages sub-unit provides technology support to industrial sectors with the overall purpose of enhancing industrial sector development. The support process involves interacting with DTI industrial sectors on a number of issues such as sector strategy (e.g. IMS), technology strategy, identification of potential areas for innovation, etc.

One of the needs that were identified as part of the process of supporting industry sectors is the need to have in-depth understanding on technological developments globally. Such understanding and the dissemination of such information is seen to be key to ensuring the long term competitiveness of South Africa’s industries in the global context.

It is for this reason that the DTI has initiated a study on technology trend analysis, benchmarking technologies capable of driving the economy and to benchmark South African technology programmes with those provided in other countries.

2.1 Project Objectives

The main objective of the study is to identify global technological trends, which will influence the competitiveness and future development of South African industries, with a specific focus on identifying areas for innovation so as to reduce industrial dependency on foreign technology, whilst ensuring that appropriate programmes are offered to promote innovation and technology

Since the findings of this study will be used for the formulation of policies, strategies and programmes aimed at growing South Africa’s technological base, broad-based recommendations regarding the above must also be formulated.

In order to achieve this objective, the following sub-objectives need to be achieved:

- Identify, on a global basis and across industrial sectors, the existing and emerging technologies (technology profiles) that are driving success in the marketplace

- Identify international trends related to technology sector development
- Identify technologies (and sectors) being supported by Governments in other countries
- Identify possible technology areas for further development in South Africa
- Identify international innovation and technology support strategies and practices which have, and are leading to sector development
- Identify cross-cutting technologies that could impact more than one sector within the manufacturing industry
- Identify the impact of introducing such technologies on industrial development as well as the general impact on socio-economic-environment conditions
- Formulate specific recommendations for government intervention, based on the above assessment, and also considering the government's current strategies and interventions

The outcome of the study will be a per-sector (and cross-cutting where applicable) identification of technology development trends, the classification of specific current and emerging technologies, the role of such technologies in sectoral development, an assessment on the relative importance of such technologies in the South African industrial development landscape, and specific recommendations for intervention. The outcome will also be a clear assessment of current support offered by governments throughout the world for technology (and sectoral) promotion, and corresponding recommendations on strengthening the role of the South African government, and specifically the DTI in technology and sectoral development.

It must be considered that this study was broad in scope (covering 10 sectors) and limited in depth, its primary purpose being to inform and provide direction for further investigation and discussion. The expected outcome was therefore not a set of specific recommendations or strategies to be pursued with regards to investment or support for the development of specific technologies, although some issues for consideration by the dti and industries in question were raised.

2.2 Scope of the Study

2.2.1 Industry sectors

The following industry sectors (with rough-cut corresponding primary SIC activity correlation) will as a minimum be covered:

- Agro-processing: Manufacture of food products, beverages and tobacco products (SIC 30)

- Clothing and textiles: Manufacturing of textiles, clothing and leather goods (SIC 31)
- Chemicals: Manufacture of coke, refined petroleum products and nuclear fuel, manufacture of chemicals and chemical products, manufacture of rubber and plastics products (SIC 33)
- Metals: Manufacture of basic metals, fabricated metal products (SIC 35)
- Minerals: Manufacturing of non metallic mineral products (SIC 34)
- Automotive and aerospace: Manufacture of transport equipment (SIC 38)
- ICT: Post and telecommunications (SIC 75) Computer and related activities (SIC 86)
- Tourism: Hotels and restaurants (SIC 64), Air transport (SIC 73), supporting and auxiliary transport activities, activities of travel agents (SIC 74)
- Biotechnology
- Cultural industries

2.2.2 Geography

The study, at a macro level, focuses broadly on global technology and sectoral development as well as global technology and innovation promotion developments. The outcome of the macro-level global assessment informs a micro-level per country (or industry sector) assessment. The micro-level assessment includes 6 countries across the globe.

2.3 Research Approach

In order to meet the stated project objectives, a two-pronged approach was followed:

Phase A) High-level technologies scan across industry sectors and countries

Identification of key technological developments in the identified sectors (and broader where applicable), a description of such technologies, and a high level assessment of its impact and relevance/importance to the South African industry.

This also included a high level assessment of technology areas of support and the nature of such support in a number of countries, as well as the impact of such activities on industrial development.

This scan was conducted by the South African research team, within international inputs about key developments, references to sources, etc. coming from out network of researchers associated with Technomic International. Although the initial proposal stated that the research will be done primarily through secondary (desk) research, an international primary research effort was needed in the form of interviews with stakeholders and experts.

Phase B) Detailed assessment of a select number of technologies within the sectors as well as detailed assessment of technology promotion activities in specific countries

Once the high level assessment has provided insight into the key areas for further investigation, additional research was done to establish a number of factors:

- Detailed description of the technologies
- Current status of development and implementation
- Existing and potential market opportunities
- Development and implementation requirements (development and implementation cost, rate of change, supportive infrastructure, required knowledge base, etc)
- Implications and potential impact for South African industry

The detailed research was primarily done through secondary research, although it relied heavily on inputs from our international network of associates (per country investigations), and included more personal interviews.

Please note that the scope and budget allowed for a maximum of 6 country specific investigations, and detailed analysis of a limited number of four technologies per sector.

THE ICT SECTOR

3 TECHNOLOGY DEVELOPMENT TRENDS OF THE ICT SECTOR

3.1 Summary

According to the OECD definition, the ICT sector/industry can be defined to be:

"The industries that produce the products (goods and services) that support the electronic display, processing, storage and transmission of information."

The major industries include manufacturing of computer hardware and telecomm equipment, IT professional services, as well as computer software and telecommunication services.

The ICT Sector is regarded s as a key sector for potential economic growth and substantial job creation in both developed and developing countries, as witnessed in the growth in this sector over the last decade. The worldwide market for ICT goods and services for the year 2002 was estimated to be in excess of $US 3 trillion (released by the World Bank in July/Aug 2003 reflecting 2002 figures).

It is expected that, over the next decade, there will be significant changes to the way information is dealt with, whether by individuals, teams, enterprises or societies. Such changes, driven by many technologies, will affect all areas of life. There will be improved mobile devices for end users, much-improved middleware, better-conceptualized standards, wider connectivity, new collaboration tools, and new and better models for doing business with information.

There will be integration requirements and a diffusion of technology into all kinds of products, resulting in the convergence of technologies. The demand for security of information will continue to increase. Computers will be omnipresent and will result in advances being made towards cheaper, faster and smaller computers as well as devices. This will enable an increase in the seamless interconnection of devices. Areas within various other markets will have an increasing reliance on ICT, particularly within medicine where the increase in the use of biotechnology is quite prominent. It is expected that artificial intelligence will be used on a more frequent basis. Another feature will be the use of vastly improved, more robust and renewable material in the manufacture of ICT equipment.

The future ICT landscape can be summarised as encompassing very unobtrusive hardware, a seamless mobile/fixed communications infrastructure, dynamic and massively distributed device networks, natural feeling human interfaces as well as improved security.

In terms of software technology there is an emergence of pervasive computing, such as distributed applications and the Wireless Web. There is a rise of platforms such as .Net and J2EE. These platforms are becoming a commodity over time, forcing the makers to keep making them better.

A rise of architectural patterns is expected, the idea being one of a pattern that provides a common solution to a common problem, within a specific context. There is also a rising level of abstraction from design patterns to architectural patterns. A rise of agile software-development methods will address the social dynamics of small teams and there is an increase in aspect-oriented programming.

Finally there should be an increase in collaborative development environments, otherwise known as virtual meeting spaces, driven by factors such as geographical dispersion.

Gartner grouped these trends into three arenas recapitulating the future landscape:

- the society will be connected and there is a need for mobility technologies which include wireless, wearables, Wi-Fi, ultra-wide band, smart phones and location-based services;
- there will be an increase in smart networked objects which include technologies like RFID, MEMS, smart dust, digital ink and embedded computing) and
- there will be semantic connectivity including technologies like Semantic Web, XBRL, automatic tagging, affinity profiles and information extraction.

An international (India and the US), as well as a local assessment of emerging technologies resulted in the following list of technologies regarded to be of utmost importance for the development of the ICT sector, globally:

- Chip technology (incorporates nanotechnology)
- Parallel computing
- Digital logic
- Mobile phones
- Wi-fi Access points (rural Wi-Fi)
- Wireless VSAT
- Smart Card system
- Database management systems
- Distributed and object-oriented application development

- Human language technologies
- E-learning (and distance education technologies)
- Telemedicine
- Artificial intelligence
  - Speech and vision capabilities
  - Artificial Neural Networks
- Geomatics
- Bioinformatics
- Digital home/media
- Mobile technologies (PDA's, mobile phones)
- Wireless communications (e.g. broadband, G3)
- Manufacturing technologies with better software standards
- Radio Frequency Identification (RFID)
- Speech recognition

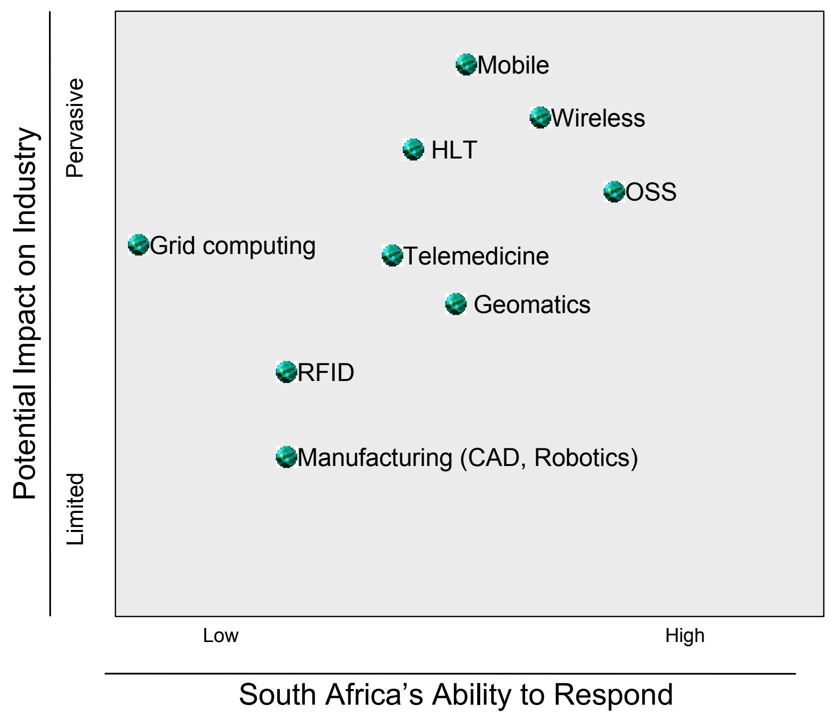
Although South Africa's share of the global ICT market is small at approximately $US 10 billion (BMI-Tech figures), the sector holds promise of being a significant and growing contributor to economic growth in domestic and export markets. Furthermore, the sector has the unique opportunity, both directly and as an enabler for other sectors, to contribute in a substantial manner to sustainable economic development, social upliftment, and empowerment. It is furthermore recognised that South Africa has strengths in a number of areas such as mobile telecommunications and security electronics. Taking such strengths, as well as weaknesses of the sector as identified in a further sections into consideration, it is concluded that the following technologies are of specific importance for the growth and continued development of the sector within South Africa.:

- Mobile technologies and devices
- Wireless network technologies
- Human Language Technologies
- Open Source Software
- Telemedicine

- Geomatics
- Manufacturing Technologies (Robotics/Artificial Intelligence)
- Grid computing
- RFID

The figure below illustrates of the potential impact of such technologies on the ICT industry, as well as South Africa's ability to respond to such emerging technologies.

Figure 1: Summary of technologies



From this figure it can be seen that mobile, HLT, wireless and OSS technologies are expected to present the most significant opportunities of the South African ICT sector. However, taking into consideration specific strengths within South Africa's manufacturing sector, other technologies such as telemedicine also need to be taken into consideration.

Mobile technology is important due to communications infrastructure being a basic requirement for all ICT initiatives. In the developing world, one of the reasons for the 'digital divide' is the lack of infrastructure and only wireless systems can effectively and efficiently address a gap like this. New connectivity technologies will enable more transparent and pervasive interaction with the environment.

Wireless networking is important, especially in rural areas. Landline and cellular telecom systems work well in metropolitan areas and smaller cities where subscribers are located in dense clusters that justify the high cost of equipment and licenses. However, connecting rural areas is a bigger challenge because subscribers are geographically dispersed, sparsely located, and economically weak therefore it is important to use wireless to leapfrog infrastructure bottlenecks. South Africa has a well developed telecommunications infrastructure and has in the past been very innovative in terms of this industry so it would be extremely beneficial to exploit this strength even further

Human language technologies are an enabling conglomeration of technologies that can address the situation of information empowerment and allows people to interact with technology in a natural fashion. It can potentially impact on issues such as illiteracy, language barriers and disability. It also allows information to be provided in technologically under-utilised regions of the country. It can enable seamless human-computer interaction - both spoken and written – which improves efficiency and user-friendliness. HLT Bridges the gap between computer literacy and availability of information to all resulting in an all information inclusive society.

Open Source Software is important because South Africa has a competitive advantage in software development and in having the ability to get software that is available for free. It has the potential to impact fundamentally on areas ranging from education to health, e-government and various spheres of business. OSS has emerged as a software model that is particularly viable in the developing world, providing local software developers with access to quality code generated by international experts; allowing users to escape from the cycle of ever-increasing international licensing fees and facilitating the development of systems that address localised needs.

RFID technology will enjoy a wide influence within the next 10 years by enabling application innovations across the full product life cycle and value chain. Applications that combine RFID data with bar coding and other inventory, pricing and identification technologies will drive the innovation of in-store retail systems, warehouse management, transportation systems and after-sale tracking of product usage, it will eventually support full supply chain management and execution

The industries that these applications will affect include, among others, the automotive, healthcare, pharmaceutical, manufacturing, warehousing, logistics and retail sector. If RFID is implemented it will allow greater accuracy of supply chain information, improved product quality and customer service. RFID therefore offers higher data storage capacities, higher identification speeds, and greater immediacy and accuracy of data collection.

3.2 Context of Sector

3.2.1 Defining ICT

According to the OECD definition, the ICT sector/industry can be defined as:

"The industries that produce the products (goods and services) that support the electronic display, processing, storage and transmission of information."

The major industries include manufacturing of computer hardware and telecomm equipment, IT professional services, computer software and telecomm services. (OECD 2002: 18; SAITIS 2003). In order to identify the various technologies and technology areas within the ICT sector a categorisation done by Gartner in 2003 subdivided the major industries into further sub-sectors as outlined below in Table. Based on these sub-sectors, the various technologies and technology areas were further developed.

Table 1: ICT sub-segmentation

Sub-Sector	Example/Description
1.Hardware, Servers & Devices including Consumer Devices	Examples: Semiconductors, Personal Computers, Battery technology, new-age hybrid consumer devices.
2.Fixed & Wireless Telecommunications & Networking	Examples: Mobile & Wireless Networking/Telecommunications, Satellite Systems, Applications, Services, Communications; Location-based services; mesh networks; broadband & Unified Communications.
3. System Development, Application Integration, Management & Security	Examples: Application Platform Suites, Integration Brokers, Platform Middleware, Web Services, Information Security
4. Supply Chain & Customer Relationship Management	Examples: Integration of technology into the Supply Chain (E.g. RFID); CRM Technologies
5.Information & Knowledge Management	Examples: Content Management, Portals, Semantic Frameworks, collaboration tools, expert location
6. Human-Computer Interaction	Examples: Micro-Electromechanical devices, embedded systems, Human Language Technology, Gesture Recognition, Speech Recognition

Source: *Adapted from Gartner 2003*

3.2.2 Background of South African ICT Sector

The ICT Sector is seen as providing the potential for economic growth and substantial job creation in both developed and developing countries. This is supported by the size and sustained growth of the global sector. The worldwide market for ICT goods and services for the year 2002/2003 was estimated to being: $3 trillion according to the figures released by the World Bank in July/August reflecting 2002 figures.

Although South Africa's share of the global ICT market is small, showing estimated figures of $11billion (South African Reserve Bank), the sector holds promise of being a significant and growing contributor to economic growth in domestic and export markets.

The sector has the unique opportunity, both directly and as an enabler for other sectors, to contribute in a substantial manner to sustainable economic development, social upliftment, and empowerment. (SAITIS, 2000)

South Africa already has an established ICT Sector with the following being key characteristics:

- Comprises of a small number of thriving large indigenous companies, some of which have achieved multi-national status.
- Several State Owned Enterprises (SOEs) that are major players in the ICT
- A growing base of ICT SMME's.
- A number of foreign-owned multinational enterprises (MNE's) that have established a presence and business relationships in South Africa.

The sector has a small but growing presence in local and export markets. It is recognised that a powerful stimulus to sector development could be achieved through stimulation of the local market for ICT products, services and applications. Such stimulation could have substantial socio-economic benefits to other sectors of the South African society by the enabling impacts of ICT adoption, particularly new and innovative applications that assist in leading the way towards realisation of an information society.

Human resources development is a most critical issue for the development of the ICT Sector and in stimulating ICT usage in other sectors of the South African society. In one respect, South Africa is no different from other countries that have to deal with the global shortage of ICT workers and, in particular, the global migration of skilled workers.

South Africa, however, faces a much more profound challenge of educating, training and integrating a large proportion of its population previously denied the opportunity to move into the emerging information society. (SAITIS, 2002)

South Africa has gained a reputation for its strengths in areas such as mobile telecommunications and security electronics but there is still a lot of work required to raise the profile of this industry on the global stage. There are definite areas in which it has a comparative advantage and in which significant gains can be made.

3.2.3 South Africa's Position

The following briefly summarises South Africa's strengths, weaknesses, opportunities as well as potential threats for the sector.

Strengths

- Innovative solutions for infrastructure development
- Provision of good quality/high technology services at relatively low cost
- ICT sector is an emerging driver of economy
- South Africa's leadership in pre-payment, revenue management, fraud prevention systems and set-top boxes
- World leaders in Banking and E-health

Weaknesses

- High rates of illiteracy and uneducated groups in SA, affecting the skills base
- ICT market relatively small
- SA is more an aftermarket, not a manufacturer of ICT
- Not a strong R&D capacity within the ICT sector
- It is a fragmented non-cohesive industry
- Skills continue to be in short supply and skills development has become a priority

Opportunities

- Developed infrastructure, communications and banking system

- Specialist areas like:
  - Business Process Outsourcing (BPO)
  - Outsourced contact centres
  - Customised software development
- IT training
- Mobile telecommunications industry
- Growing GSM market
- International links with multinational organisations
- In many ICT sub-sectors adoption of technology is as sophisticated as that found anywhere in the world.

Threats/Barriers

- Brain drain – skilled workers looking for employment in other countries and areas
- Technology is relatively expensive
- Destruction of local manufacturing capacity by imports
- Inadequate local manufacturing capacity
- Can't keep up with pace of global skills development resulting in inability to develop markets
- Security
- Lack of support to SME
- Lack of skilled Human Resources
- High equipment and testing costs
- Slow network rollouts in rural areas

3.3 Global Technology Trends

Global trends dictate where the industry is developing and where further advancements need to be made in order to remain globally competitive. Below is a list of the main drivers of change that characterise this industry at the moment, (DERA: 2001).

- There is a growth of ICT due to increased technological globalisation and greater sophistication of computers.
- There is an increasing need for mobility and accessibility resulting in a focus on wireless and mobile technologies.
- Integration requirements and cost and open system and standard based product development are necessary
- Diffusion of technology into all kinds of products resulting in convergence of technologies – between computing and telecommunications, and also with broadcasting and publishing.
- Digital technologies allow all forms of information – voice, data or video – to be manipulated across all types of devices and networks.
- There is an increased demand for security of information
- Advance towards cheaper, faster, smaller computers and devices, due to a combination of other technical advances and ubiquitous computing.
- Due to the devices becoming smaller, lighter and more powerful it becomes easier to interconnect devices seamlessly.
- Sharing of data processes and applications
- Cost of software is becoming more and more expensive resulting in a demand for Open Source Software
- Trend to access cheaper labour markets and skills therefore offshore outsourcing is increasingly occurring.
- Access to technology: Increasing access to ICT or creation of a ‘knowledge gap’ as information access is restricted to those who can afford it.
- There is an increasing reliance on ICT within areas like business, medicine, industry and leisure.
- There is an increase in the use of biotechnology (including genetic engineering), particularly in medicine. ICT plays a prominent role in this development due to its cross cutting characteristics.
- The use of Artificial intelligence is on a more frequent basis.
- Use of vastly improved, more robust and renewable materials.

- A world characterised by computing that is omnipresent, ubiquitous communication and intelligent user interfaces.
- A world of ambient intelligence (network of hidden intelligent devices aware of human presence and able to respond accordingly)
- In terms of software the key trends as identified during an interview by Grady Booch (chief scientist at Rational Software Corporation) are said that the technologies will get more complex over time, and these growing complexities need to be addressed.
- The emergence of pervasive computing, such as distributed applications and the Wireless Web.
- There is a rise of platforms such as .Net and J2EE. These platforms are becoming a commodity over time, forcing the makers to keep making them better.
- The rise of architectural patterns. The idea of a pattern is providing a common solution to a common problem in context. There is a rising level of abstraction from design patterns to architectural patterns as well.
- Rise of agile software-development methods. Agile methods address the social dynamics of small teams, for which the Rational Unified Method does not.
- There is an increase in aspect-oriented programming. If the complex systems are analysed there is no single view that really describes the interesting complexity but aspects like security cuts across those views.
- There is an increase in collaborative development environments other wise known as virtual meeting spaces because there is an increase in aspects like geographical dispersion.

To summarise the above the technologies can be classified under three mega trends as identified by Gartner (2003) namely:

- Connected Society (wireless, wearables, Wi-Fi, ultra-wide band, smart phones, and location-based services).
- Smart Networked Objects (RFID, MEMS, smart dust, digital ink, embedded computing).
- Semantic Connectivity (Semantic Web, XBRL, automatic tagging, affinity profiles, information extraction).

3.4 Case Studies

The countries that were selected for case study were US and India. The US is a good case to look at in terms of them being a highly industrialised country and leaders in the use of sophisticated technologies. The United States tops the rankings this year (2004) on the Networked Readiness Index 2003. This is primarily due to its superior ranking in the usage of ICT by businesses and the government. The country also remains the most innovative in the world, which has allowed it to maintain its leadership in the rankings over the last three years.

India is a developing country and faces many similar socio-economic challenges similar to South Africa. In recent years India achieved significant prominence in software development, which is an important area South Africa can play in.

3.4.1 US

The research that was done internationally resulted with the following findings.

The US is the leaders in technology and has the highest number of scientist as well as patents. An important fact to remember is that ICT accounts for 20% of all US patents. The US ICT sector translates to 35% of the global ICT market where Japan is second with 11% and Germany third with 7%. ICT manufacturing accounts for 12% of the total US manufacturing and service production.

Despite its relatively modest share of total US R&D funding, the federal government's role is critical to the nation's science and technology enterprise. Federal agencies support a majority of the nation's basic research and 58% of the R&D performed in US colleges and universities. Basic research is the primary source of new knowledge that ultimately drives the innovation process.

Within the General Science, Space, and Technology function, the federal government supports areas of cutting-edge science, through the National Aeronautics and Space Administration (NASA), the National Science Foundation (NSF) and the Department of Energy (DOE). The results of basic research are unpredictable, developing performance goals for this area present a number of unique challenges.

Each of these agencies funds research and contributes to the Nation's cadre of skilled scientists and engineers. As a general goal for activities in this function, at least 80% of the research projects will be reviewed by appropriate peers and selected through a merit-based competitive process.

Another important federal role is to construct and operate major scientific facilities and capital assets for multiple users. These include telescopes, satellites, oceanographic ships, and particle accelerators. Many of today's advances in medicine and other fields rely on these facilities. As general goals:

- Agencies will keep the development and upgrade of these facilities on schedule and within budget, not to exceed 110% of estimates; and
- In operating the facilities, agencies will keep the operating time lost due to unscheduled downtime to less than 10% of the total scheduled possible operating time, on average.

The budget proposes $21.2 billion to conduct activities in support of general science, space and technology. The government also stimulates private investment in these activities through over $8.4 billion a year in tax credits and other preferences for research and development (R&D).

The applications concentrated on are technologies like:

- RFID
- Sensor nets
- Wireless communication platforms.

Government is not really pushing the adoption of ICT aggressively but rather has an initiative for Nanotechnology. Majority of the spending is also going towards the defence and military area of the country.

According to the International research conducted 2 key governmental agencies that support ICT were identified within the US.

1. National Science Foundation

This foundation initiates and supports research for ICT. The programmes being covered are Computer and Information Sciences as well as human computer interaction and computer design.

2. Defence Advanced Research Projects Agency

This is the central research and development organisation for the Department of Defence. They manage and direct basic as well as applied research. There is information processing technology office with one of the key objectives to address Human Language technologies among others

The table below shows a summary of the general Science, space and technology spending that is occurring within the US.

Table 2: Support and Funding in the US

Federal Support of General Science,Space and Technology (in millions of Dollars)							
	2000	2001	2002	2003	2004	2005	2006
	Actual	Estimate					
Spend	19,203	20,861	21,191	21,892	22,441	22,910	23,488

3.4.2 India

India is a very good case study for the ICT sector because it is an excellent role model for any developing country. The IT industry as share of GDP has increased from 1.22% in 1997 to an estimated 3.15% in 2003. The size of the IT sector has increased from US$ 5 billion to US$ 16.4 billion over this same time period. The success of the Indian ICT sector has also enhanced India's export performance. While software exports accounted for around 5% of India's total exports in 1997, this share is more than 20% in 2003.

Due to multiple reasons, including a high level of regulation in many sectors, government apathy to computerisation initiatives and high tariff rates for hardware, domestic investment in ICT has been stunted. India currently spends a small fraction of its GDP on IT – about 1.1% – when compared to the US which spends 5% of its GDP on IT.

One of the key technology trends that India, apart from its significant success in Software Development and Programming, is its attempt to focus on is the use of Information Technology in the Biotechnology area. This is a natural fit for India, given its prowess in IT and its extremely talented pool of researchers, medical doctors and technicians in the Biosciences field. This IT role is also likely to be a factor in other areas of science and engineering including design of integrated chips and other science/technology sectors.

The other area of technology that India has focused on is the entire telecommunications area and connectivity both locally and internationally.

- Has enabled doctors in India to diagnose X-Rays that are taken in the U.S and sent electronically to India for processing overnight.

- Diagnosis returns to U.S. the next morning, in time for patient visit there. (Example of the breadth and scope of outsourcing boom in India).

- Diagnosis is at a fraction of the cost of U.S. doctor.

The Indian government had historically been a barrier to the growth of the ICT industry by requiring approvals for all investment, especially from foreign sources and a bureaucracy that was somewhat corrupt and short-term in orientation.

The private industry in India had been stifled by government bureaucracy and government investment in key sectors of the private sector economy Telecom was still controlled by state-owned departments of Post and Telegraph, especially the landlines.

The IT industry and the mobile Telecom industry were new areas of growth that the central and state governments had not taken a major commercial position in because they did not have expertise in these areas. It was a new area and the government realized its incapability to participate in an industry in which changes occurred at a very rapid pace.

Essentially government realized that private industry would grow the market if government just “moved out of the way.” And any government programs or policies would be to provide the infrastructure in telecommunications, “connectivity” and educational system (which was already in place since the 1950’s) to enable private industry in the IT and Telecom area to grow. The government also realized that the growth of these two areas, IT and Telecom, are inter-related and government programs should consider this key relationship.

Therefore the Government has developed the following support programmes and mechanisms:

Centres of excellence

- Indian Institute of Information Technology which is a centre of Excellence in IT Education & Research. It is a Joint endeavour of IT industry and Government and includes IBM, Oracle,PSI-Net, Satyam & Motorola Schools
- MSIT Program consists of a consortium of Universities including Carnegie Mellon University
- Indian School of Business which includes Wharton & Kellogg Schools
- Centre for Good Governance including DFID and the Kennedy School of Government

Ministries

The Central government in India is organized under Ministries, with multiple Departments within these industries, and sub-departments/centres under the departments.

Ministry of Communications and Information Technology

This is the government ministry focused on IT/Telecom.

Department of Information Technology

The Centre for Development of Advance Computing (CDAC).

- Headquarters in Pune, with multiple centres involved in government sponsored and private sponsored research in core areas of IT that are not possible at individual private companies.

CDAC has the following key programs/initiatives in areas of the IT/Telecom industry:

Table 3: Programmes and Initiatives by CDAC

Broad Areas	**Specific projects**
Geomatics	GIS-based solutions. Decision-support systems.
Business computing	Data warehouses, Data mining, Telecom Service Solutions.
Hardware technology	System Area network Reconfigurable computing Systems.
Medical Informatics	Telemedicine (Clinical care at a distance for 2nd opinions teleradiology, telecardiology). Hospital Information Systems
Systems Software	Parallel programming. High performance communication subsystems. High performance storage system (scalable)
Applications in Science and Engineering Computing	Computational Atmospheric Science Computational Structural Mechanics. Computational Fluid Mechanics. Bioinformatics (Molecular modelling, genome sequence analysis)
Networking and Internet Software	WI FI Technology Crypto for Network Security
E Governance	Improve efficiency, convenience, transparency, and accessibility of citizens to the government departments.

Broad Areas	Specific projects
Geomatics	GIS-based solutions. Decision-support systems.
Business computing	Data warehouses, Data mining, Telecom Service Solutions.
	Pilot projects in National ID, citizen databases, Smart Card Successful efforts in automation of land records in Karanataka. Establishment of a National Institute of Small Government, a Section 25, non-profit company.

ERNET (Internet/networking group).

- Largest nationwide terrestrial and satellite network with presence at education/research institutions and major cities. Provide R & D funding, training and Internet Access through this initiative. Integrated satellite/WAN, broadband, SCPC and VSAT technology. Also a fibre-optics backbone and an initiative in security/virus protection. Also this centre is responsible for key initiatives in Internet-based education and E learning.

Electronics & Computer Software Exports Promotion Council

- Includes 2200 manufacturers and exporters. Provides market studies and market data on 175 countries regarding export markets to assist domestic companies, facilitates JVs, maintain a database of companies in IT/Telecom in India that could be used by foreign companies trying to source from India.

Centre for Materials for Electronics Technology.

- Established in 1990 including 3 labs, 39 government-sponsored and private sponsored projects in areas such as high-purity materials and specialty materials like Tantalum, high purity Indium, Solar Cell grade POCl3, Cadmium, Tellurium, Nano-sized AG-Pd copowders, sub-micron sized Ag (Silver) powders.

Software Technology Parks

- A total of 18 parks, with 5700 commercial units in these parks, including multiple centres in Bangalore, Pune, Secunderabad, Chennai and other areas that includes satellite communications infrastructure provided by the government to establish connectivity with locations outside the country (International Gateway called STPI and connecting with INTELSAT to locations in North America).

- Examples of such parks are HITEC City in Hyderabad and TIDEL Park in Chennai. Also tax-breaks and incentives to invest in these areas and create employment. New government initiatives to create such parks in rural areas to spur development in under-developed areas.

Ministry of Science and Technology

This is the other relevant central government ministry whose goal is to promote research and development in many key technology sectors, including IT and Telecom.

Department of Science and Technology

SERC

- Composed of eminent scientists, technologists and other from various universities, labs and private industry to create an advisory group regarding the direction of R & D and allocation of resources.

- Program Advisory Committees assist SERC in various disciplines of Science and Engineering.

IRHPA (Intensification of Research in High-Priority Areas)

- Including creation of Core Group/units around an outstanding scientist for each area, setting up national facilities in areas of high priority, evolving nationally coordinated programs in multi-disciplinary areas (e.g. leverage India’s strength in IT and combine it with its strength in medicine to create such programs as Tele-medicine and Bioinformatics), and training young scientists to pursue R & D in these areas.

- Core strategy is to strengthen R & D infrastructure at host institutions built around an outstanding scientist at each of those institutions.

- They also focus on Inter-Institutional and inter-disciplinary programs in R & D.

3.4.3 Lessons Learnt

The ICT revolution of the last two decades offers developing countries unprecedented and low cost opportunities to compete in the global economy - leapfrogging stages of development and substituting human for financial capital as the key factor of production.

Emerging technologies offer new opportunities for improving the livelihoods and quality of life for poorer people in developing countries. There is, however, also a very real danger of a growing divide. If this is not addressed and developing countries (or marginalised groups within developing countries) remain essentially outside of this 'new economy', the consequences for poorer people will be very damaging.

A major constraint to investment in ICT's in developing countries has been the absence of a sound legal and regulatory environment for competitive telecommunications and broadcasting sectors. This is particularly an issue in Africa where the media and communications industries remain extensively state-controlled and where, for lack of competition, international telecommunications and Internet connectivity are excessively expensive.

The following are key insights from the Indian case study:

- The Indian government policy with respect to IT/Telecom has been to "stay out of the way" of the Indian private technology sector.
- They provide a "good climate" for growth by doing the things that government can do in terms of connectivity, educational infrastructure and some limited tax incentives
- This has spurred private industry, especially foreign private industry, to make investments in India which has proven to boost exports and employment within the Indian sub-continent.
- The area of technology that India has focused on is the entire telecommunications area and connectivity both locally and internationally because they realised that connectivity"/Telecom is key to growth of IT industry
- India is good with IT and has an extremely talented pool of researchers, medical doctors and technicians in the Biosciences field so they are therefore trying to focus their ICT in the Biotechnology area.
- Technical innovation from the software hotbeds of India and the ever-changing tides of the Internet pose an increasing challenge for established software companies.
- Government is creating initiatives to create Software Technology Parks to establish connectivity with locations outside the country and in rural areas to spur development in under-developed areas.

3.5 The Future Landscape of ICT

The above provided a context into which the ICT sector can be placed as well as providing a case study of what other countries are doing to develop the ICT sector. It is important to establish what the future vision of ICT will be and the requirements that are needed in order to take advantage of this vision.

The development of the future ICT landscape provides an image of an Information Society that emphasises greater user-friendliness, more efficient services support, user empowerment and support for human interactions. People will be surrounded by intelligent interfaces that are embedded in all kinds of objects and the environment will be capable of recognising as well as responding to the presence of diverse individuals in a seamless and inconspicuous way.

The future ICT landscape can be summarised as encompassing very unobtrusive hardware, a seamless mobile/fixed communications infrastructure, dynamic and massively distributed device networks, natural feeling human interfaces as well as security. Gartner identified specific trends which are grouped into three arenas recapitulating the future landscape.

The society will be connected and there will be a need for mobility technologies which include wireless, wearables, Wi-Fi, ultra-wide band, smart phones and location-based services; there will be an increase in smart networked objects which include technologies like RFID, MEMS, smart dust, digital ink and embedded computing and there will be semantic connectivity which includes technologies like Semantic Web, XBRL, automatic tagging, affinity profiles and information extraction.

Requirements for future ICT landscape:

To develop unobtrusive hardware the technology requirements are self-generating power and micro power usage in objects, for example low power radio frequency chips. Breakthroughs in input/output including new displays, smart surfaces, paints and files which have smart properties are also necessary. This is a foundation to the seamless interfaces and invisible interactions with the intelligent environment.

Other technologies which need to be taken into consideration are active devices such as sensors, posture and environment or smart materials that can change their characteristics or performance by stand alone intelligence or by networked interaction. Nanoelectronics will also be indispensable and other such nanotechnologies, which permit miniaturisation trends to extend beyond the limits of micro-devices through hybrid nano-micro tools. Nano devices would have the ability to yield lower power consumption, higher operation speeds and high ubiquity. There should also be a human factor design emphasis so that the widespread embedding of computers produces a consistent environment rather than a large number of electronic devices with IP addresses.

To develop a seamless mobile/fixed communications infrastructure the technologies that will be required are a completely integrated set of mobile and fixed networks (operating with equivalent to IP technology) and broadband networks (core and access broadband networks are likely to converge).

The ICT environment in 2010 is likely to be a world within which there are uncountable interoperating devices. Some of these will be wires, some wireless, and many mobile while many more will be fixed. Therefore in order to develop large distributed device networks, it would be important to have databases that are accessible on demand from anywhere within the system as well as configurable networks, therefore multi-domain networking (where new computer and communications architectures will be necessary), adaptable new systems software; embedded intelligence; data management and storage systems will be needed. The key to all of the above will be the development of middleware and agent technologies.

In order to develop natural feeling human computer interfaces, artificial intelligence techniques will have to be employed. The key issue which needs to be resolved is to provide structured databases to the families of systems which can operate across all domains to general levels. There will also be a demand for supportive and technological equivalents to user interface designs like speech, gesture and pattern recognition. These technologies will need to be adaptive to users needs. Speech recognition will have a large impact on allowing hands free operations and automatic identifications.

A regular theme of the new ICT landscape is safety, security and dependability, therefore in order to develop this, the technologies that will be required will be various software technologies and techniques that are based upon the security software components. It will also be very important to have systems that are secure against deliberate misuse, therefore various techniques will be necessary like secure ID authentication, micropayment systems and biometrics. Biometrics will be very important as a means to authenticate based on measurable physical characteristics. Various security technologies like encryption as an example will be necessary in order to develop the trusting environment, incorporating secure authentication and payment systems.

Table 4: Key enabling technologies

Embedded intelligence	Virtual and interactive reality Real time transmission of multimedia Software engineering and components Intelligent homes Intelligent identifiers, autonomously communicating objects
Middleware and distributed systems	Big Server networks Integration of appliances, XML, and other advanced languages
IP Mobile and wireless	PDA’s
Multi-domain network management	Quality of IP service
Converging core and access networks	High backbone networks
Micro and opto-electronics	Silicon and micro electronics Optic-electronics and photo-components

	Search engines and intelligent indexing Micro-electronics Micro energy batteries Mass memories Flat screens
Security tools	Encryption
Multi-modal and adaptive interfaces	Virtual and interactive reality
Multi-lingual dialogue mode	Speech recognition Linguistic and vocal technologies

Source: *Adapted from Rapport technologies-Cles 2005. Ministere de l economie et de l;industrie. Paris, 2000*

The rich diversity of technologies featured in the future landscape of ICT will give rise to various business opportunities and business models.

Therefore some of the key features of the new business landscape which emerges, as identified by the ISTAG (2001), places an emphasis on:

- Initial premium value in niche markets within industrial, commercial or public applications where enhanced interfaces are needed to support human performance in fast moving situations.
- Start up and spin-off opportunities from identifying potential service requirements and putting the services together that meet these new needs
- Audience or customer's attention as a basis for free and user services paid for by advertising or complementary services or goods
- Self-provision based upon the network economies of very large user communities providing information as a first or at an almost zero cost.

The table below identifies the current and future technological focus areas as identified during the international research done in India and US. The comparison is shown below including South Africa. The most common technology focus areas are mobile phones, wireless networks, HLT and Geomatics.

Table 5: Focus areas for technologies

	1.Hardware, Servers & Devices including Consumer Devices	**2.Fixed & Wireless Telecommunications & Networking**	**3. System Development, Application Integration, Management & Security**	**4. Supply Chain & Customer Relationship Management**	**5.Information & Knowledge Management**	**6. Human-Computer Interaction**	**7. Other**
South Africa		Mobile phones Wireless Technologies: VSAT Wi-Fi Public Access points Smart cards	Manufacturing technologies (Robotics)	Supply Chain Management	Portals Open Source Software	Human Language Technologies E-learning Telemedicine	Geomatics GIS, GPS, Remote sensing
India	Chip technology (incorporates nanotechnology) Parallel computing Digital logic	Mobile phones Wi-fi Access points (rural Wi-Fi) Wireless VSAT Smart Card system			Database systems Distributed and object-oriented programming and systems	Human language Technologies E-learning Telemedicine Artificial Intelligence Speech and vision capabilities	Geomatics Artificial Neural Networks Bioinformatics
US	Digital home/media	PDA's Blackberries Mobile phones Wireless broadband/communications	Manufacturing technologies with better software standards	Radio Frequency Identification (RFID)		Human Language Technologies Speech recognition	

3.6 Requirements of Future ICT Technologies

3.6.1 Identification of technologies

The next section reviews some technological developments that may have a substantive impact in fostering participation in the ICT revolution of a developing country as the ICT evolution continues. These technologies/technology areas include technologies that are perceived as having the most impact or that are likely to be affected by over -hype. The mobile and wireless area continues to dominate in terms of innovation with other technologies that will be useful within the South African context. The technology areas/technologies include:

1. Mobile technologies
2. Wireless Networks
3. Human Language Technologies
4. Manufacturing technologies - Robotics
5. RFID
6. Geomatics – GIS/GPS
7. Medical Technologies - Telemedicine
8. Grid computing
9. Software – Open Source Software

3.7 Description and Analysis of Technologies

3.7.1 Mobile Technologies

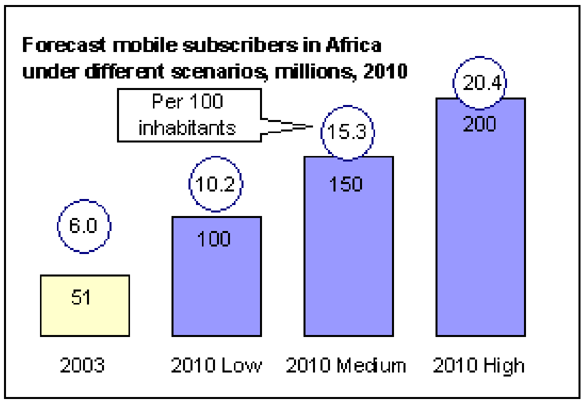
Communications infrastructure is a basic requirement for all ICT initiatives. In the developing world, one of the reasons for the 'digital divide' is the lack of infrastructure and only wireless systems can effectively and efficiently address a gap like this. New connectivity technologies will enable more transparent and pervasive interaction with the environment. The mobile phone can be considered to be one of the technological devices helping developing countries to rapidly close the communications gap.

The mobile world is going to change massively. People will start using mobile technology to access the net, simply because it will be faster. Its proven technology and it makes true wireless networking a distinct possibility.

The telecommunications industry is changing on a continuous basis. New technology is creating opportunities, and telecom companies are racing to keep up. The convergence of the Internet, cellular phones and PCs, plus growing access options through wireless, fiber optic, satellite and DSL, promise a constantly connected global society. Communications technology is tearing down barriers between countries, cultures and communities. Information is exchanged with the push of a button, and the most remote locations are now accessible via the cellular or satellite phone.

The telecommunications industry encompasses the movement of voice, video and data over distances, long or short. It is comprised of local exchange, wireless service of all types (including cellular phones, pagers and palm-type devices), satellite broadcast, fiber optics, copper wire, undersea and coaxial cable, the Internet, microwave, private networks, long distance service and video-conferencing.

Figure 2: World's growing mobile market



Source: Adopted from: *http://www.3g.co.uk,2004*

- **GPRS (General Packet Radio Services)** - is an 'always on' communication service that transfers information in the same way the Internet does: by breaking data up into 'packets' that each follows their own, shortest-available route to their destination, where they are reassembled.

  GPRS has been designed for the transmission of data rather than voice, so for example a telephone call is received while looking for something on the Internet, the session will be paused while taking the voice call, and will resume once done.

  Applications of GPRS include when connecting to a laptop or PDA to the Internet, it will be at speeds similar to those that can be achieved from conventional modems.

  Other applications include web browsing, MMS, e-mail, information services, e-commerce applications, document sharing, remote networking, file transfer, chat and video conferencing.

- **Micro Fuel Cells** - An alternative power source to batteries for mobile devices. They have the potential to provide 10 times the energy of lithium ion batteries (see "Micro Fuel Cells Power Mobile Devices," T-18-6478). This will improve equipment usage life and facilitates more powerful mobile devices and applications.

- **Smart phones** - A smart phone is a mobile terminal that can send and receive voice and data calls. Although a smartphone is voice-centric, it can run data applications without a network connection resulting in anywhere, anytime computing

- **Location-aware services** - use cellular network technology to provide services that are relevant to a specific user location. Services include safety, information and tracking. Privacy is a significant hurdle but productivity and real-time collaboration will be impacted.

- **Speech recognition**: Turns human speech into text or commands, and enhances data input by using voice instead of typing data into small, uncomfortable keyboards. Can make accessing phone details and data applications easier in mobile phones and personal digital assistants, and will also be useful in on-board devices (for example, car navigation systems) for hands-free human interaction.

- **Alternative displays**: Traditional liquid crystal displays (LCDs) are not suitable for next-generation mobile devices because of their high power consumption, manufacturing costs and weight. New display technologies are emerging, such as digital paper, organic light-emitting diodes (OLED) and "heads-up displays," that will improve portable device screens and their data visualization capabilities.

- **"Haptic" technologies**: Uses vibrations and movements of the mobile device to transmit information to the user by touch. This additional form of output enhances the user experience for applications such as gaming, music and videos.

- **New power sources:** Increasing demand for longer battery life and power in sophisticated mobile devices will be addressed by new technologies such as fuel cells, body heat batteries and micro-electromechanical systems (MEMS).

- **Wearable devices**: Most wireless equipment and gadgets could migrate into clothes, garments and fashion accessories, minimizing the need to carry heavy devices. (Gartner, 2003)

3.7.2 Wireless Network Technologies

Wireless is the latest buzzword in the technology world. When people say "wireless" they usually mean the "wireless internet". The wireless Internet encompasses any device that can access a data network wirelessly. That access may be triggered by data or voice input. Examples are wireless-internet-enabled cellphones, wireless PDAs, wireless PocketPCs and laptop computers with wireless modems.

Wireless is a term used to describe telecommunications in which electromagnetic waves (rather than some form of wire) carry the signal over part or the entire communication path. Some monitoring devices, such as intrusion alarms, employ acoustic waves at frequencies above the range of human hearing and are also sometimes classified as wireless.

Telecom services, especially in rural areas, are a key challenge for developing countries. Landline and cellular telecom systems work well in metropolitan areas and smaller cities where subscribers are located in dense clusters that justify the high cost of equipment and licenses. However, connecting rural areas is a bigger challenge because subscribers are geographically dispersed, sparsely located, and economically weak therefore it is important to use wireless to leapfrog infrastructure bottlenecks.

Common examples of wireless equipment:

- Cellular phones and pagers — provide connectivity for portable and mobile applications, both personal and business
- Global Positioning System (GPS) — allows drivers of cars and trucks, captains of boats and ships, and pilots of aircraft to ascertain their location anywhere on earth
- Cordless computer peripherals — the cordless mouse is a common example; keyboards and printers can also be linked to a computer via wireless
- Cordless telephone sets — these are limited-range devices, not to be confused with cell phones
- Home-entertainment-system control boxes — the VCR control and the TV channel control are the most common examples; some hi-fi sound systems and FM broadcast receivers also use this technology
- Satellite television — allows viewers in almost any location to select from hundreds of channels
- Wireless LANs or local area networks — provide flexibility and reliability for business computer users

Wireless technology is rapidly evolving, and is playing an increasing role in the lives of people throughout the world. In addition, ever-larger numbers of people are relying on the technology directly or indirectly.

More specialised examples of development for future wireless communications and control include:

- **Global System for Mobile Communication (GSM)** — a digital mobile telephone system used in Europe and other parts of the world; the de facto wireless telephone standard in Europe

- **General Packet Radio Service (GPRS)** — a packet-based wireless communication service that provides continuous connection to the Internet for mobile phone and computer users

- **Enhanced Data GSM Environment (EDGE)** — a faster version of the Global System for Mobile (GSM) wireless service

- **Universal Mobile Telecommunications System (UMTS)** — a broadband, packet-based system offering a consistent set of services to mobile computer and phone users no matter where they are located in the world

- **Wireless Application Protocol (WAP)** — a set of communication protocols to standardize the way that wireless devices, such as cellular telephones and radio transceivers, can be used for Internet access

- **i-Mode** — the world's first "smart phone" for Web browsing, first introduced in Japan; provides color and video over telephone sets

- **Ultrawideband** – this is a personal-area network technology that uses pulsed radio techniques to transmit data. It is a possible high-bandwidth successor to Bluetooth. It will enable higher speed and low cost network services. Experts say that eventually the limit will rise to 1 gigabit per second. UWB has the potential to displace not only Wi-Fi, but also the technologies that are used to build large-scale wireless voice and data networks, such as CDMA, GPRS/GSM, EDGE and W-CDMA.

- **Fourth-Generation Wireless Technology** - Fourth-generation (4G) wireless technology is a next-generation, wide-area technology that potentially offers high capacity to support "packetised" voice and more than 10-Mbps connection speeds, resulting in high-speed communications and multiple network as well as system interoperability.

- **Bluetooth** - is a wireless networking technology that allows devices in a 30-foot range to transmit data between one another. The technology is designed for mobile devices such as cell phones, PDA's and mobile computers.

- **Mesh networks** - Mesh Networks are developed from peer-to-peer routing technology. Packets can be routed around bottlenecks and failed nodes to maintain end-to-end connections, there is a low corporate need for such technology but it will improve connectivity options for remote access.

- **VSAT -** It is used in networks that primarily support point-to-multipoint communications as part of large private networks. The technology is best applied within locations that are not easily accessible. The use of an application like Voice over Internet Protocol (VoIP) reduces the cost of service to low-income people.

In order to take advantage of the global trend of a wireless society, infrastructure, telecommunication, affordable technology, regulation around the infrastructure and wireless enabled access points are important. Security is also an essential concern to take into consideration.

SA has a strong telecommunication infrastructure therefore creating a strong position in terms of these technologies. South Africa has already been innovative in this area, a good example is the creation of the sophisticated pre-paid systems, which spurred the phenomenal growth of cellular subscribers, and this has now been adopted throughout the world.

The South African wireless payments group was also one of the first bodies to set architectural standards for future mobile payment systems.

There is a strong telecommunication infrastructure in comparison to the rest of Africa, the fixed line technologies installation is relatively inexpensive and rapid, costs to maintain this technology as well as the technical expertise needed for maintenance of the equipment is quite economical

Wireless opportunities among others include Wi-fi public access points, mobile application development in automotive industry, Radio tagging for identification and logistic, specialised communications in inaccessible terrains and remote sensing.

3.7.3 Human Computer Interaction

Speech Recognition for Telephony and the Call Center

Speech-recognition systems interpret human speech and translate it into text or commands. Telephony and call center applications allow automation of tasks through a speech recognition dialogue with the caller. Adoption of speech recognition for the call center is moving beyond early adopters and gaining acceptance as a viable automation tool. The need for careful application selection and design is causing slower adoption than for other self-service approaches (for example, the Web). Areas that this technology is most likely to impact is travel reservations, order status, ticketing, stock trading, directory services, auto attendants and name dialing.

Human Language Technologies (HLT)

Technologies that use knowledge about spoken and written language and about developing computer software to recognize, analyze, interpret and generate language (Lackwood and Joscelyne 2003). The technologies that are used here are speech recognition, speech synthesis, language translation technology and spoken language understanding technology.

This technology is an enabling technology which can address the situation of information empowerment and allows people to interact with technology in a natural fashion. It undertakes to solve various issues like illiteracy, language barriers and disability. It also allows information to be provided in technologically under-utilised regions of the country. (CSIR: 2004). It also enables seamless human-computer interaction - both spoken and written – which improves efficiency and user-friendliness.

HLT Bridges the gap between computer literacy and availability of information to all. The speech technology can be utilised for interaction with various databases of information and it can be accessed through various means like telephone, information kiosks and the internet.

In terms of industry linkages it has the potential to facilitate government service delivery, stimulate economic activity, facilitate crime prevention and enhance tourism by having an accessible multilingual technology. It can also be developed to be exportable to other developing countries that are in similar situations.

Resource development is a very important requirement as well as additional research and development. The deployment of the various technologies is necessary as well as having a storage capacity for a massive information load. Other requirements include greater innovation, better infrastructure, more investment, strong systems integrators and large storage spaces for advanced language dictionaries,

Implications of HLT:

- Bringing information to all citizens in their respective languages.
- Allowing informed and fully information inclusive population
- Knowledge empowerment
- Cultural and language diversity
- Skills development, training, education

South Africa has already invested a reasonable amount of money into the development of HLT. The potential impact of the technology in South Africa could be significant since South Africa has the challenge of providing services to people in 11 languages, many of them illiterate. Commercial enterprises can gain productivity levels through HLT, especially within those areas and industries that have lower levels of literacy.

The South African Government is a potential market driver as it pursues service delivery to all South African's. The technology can also be exported to other countries with similar issues as a unique solution.

3.7.4 Manufacturing technologies

Robotics

A reprogrammable, multifunctional manipulator designed to move material, parts, tools, or specialized devices through various programmed motions for the performance of a variety of tasks. Robotics is very important as an emerging technology for manufacturing therefore quite a bit of emphasis has been placed on this.

Robotics is expected to rival the automobile and computer industries in money and jobs. According to the Robotics Industries Association, a trade association representing companies in the robotics industry, the use of robots in the electronics industry should grow an average of 35 % a year over the next couple of years.

Robotics defined by its functions is carved up into four broad sub-sectors:

1. **Industrial robots** used in manufacturing industries for welding, painting and feeding components into machines. These are programmable robots and not smart. If something should go wrong and an assembly line breaks down, the robots will keep on aimlessly moving, accomplishing nothing. They're not capable of reacting to change.

2. **Personal robots**, most of which are expensive high-tech toys. The consumer market for personal robotics products appears to be in the process of changing for the better, though it's a slow transformation to be sure. Thanks to lower manufacturing costs and the improved performance of mass-produced computers, a number of small companies are starting to offer consumer robots that can clean and maintain a household.

3. **Medical field**. One of the cutting edge applications is in the development of surgical robots. Surgical robots can do everything from tying sutures to moving cameras in response to spoken commands.

4. **Autonomous robots**, touted as the next generation of robots. Unlike the programmable robots, autonomous robots make decisions determining right from wrong and capable of socializing with people and eliciting emotions like surprise, happiness, disgust and anger. Most autonomous robots are being developed at universities such as Carnegie Mellon University and MIT.

Applications of Robotics

- Welding: Welding has been the largest application of robotics worldwide. They are used to weld together auto chassis and electrical appliances. The popularity of robots in welding is due to their precision and lack of aversion to repetitive motions.

- Material Handling: This application involves the transfer of a part from one machine to another. Due to the simplicity of motion, this is one of the earliest applications.

- Die Casting: Die casting is the process of injecting molten metal into a metal mold and then allowing them to solidify before being removed for finishing.

- Machine Loading and unloading: This is more complex than the previous application. Here, the robot takes a piece, orients in properly and loads it into a special purpose machine, such as a C.N.C. lathe or milling machine. The purpose is to cut lead times, lower direct and indirect labor costs and increase production volume

- Spraying: The ability for robots to perform consistent motions has had great impact on spraying applications. One of the key factors for introducing robots in spraying applications is the work environment. The area must be dust free and at the right temperature which limits the size of a spray painting station.

- Assembly: There was a rapid increase in the use of robot for this application in Japan as sensing and control systems for robots improved.

- Inspection: Inspection deals with sorting and searching of parts to put them into separate bins or conveyor belts. They also deal with detecting defects and removing them. Many of these forms of robots were used in the 1980's when they could be integrated with TV cameras and fiber optics. Robots are also now being used for luggage inspection at airports.

- Hazardous Waste Cleanup and Bomb Disposal: Robots are used in nuclear power plants and by police and military to handle hazardous materials.

In order for robotics and artificial intelligence to be successful within the various industries it is necessary to have the significant infrastructure, comparable computer software as well as computer power and to have the necessary investments to be able to cover the costs, skilled operators and managers are also crucial.

South Africa’s is in a strong position due to the exceptional software development capabilities, but there is a need to improve on skills and development as well as improve on manufacturing infrastructure.

Robotics within manufacturing creates the ability to improve quality and improve efficiency as well as the optimal utilisation of the manufacturing industry. The improvement of quality in manufactured products allows these products to become more marketable and exportable to other countries, it also enables manufacturers to meet productivity and cost reduction demands of a competitive global market.

Future Robotics Applications include:

Excavating and grading land, Climbing and painting rusty utility towers , Working in conjunction with doctors to perform hip replacement surgery, Putting up and maintaining space stations, Robotics Markets, Industrial, Space, Healthcare, Personal consumer, Automotive and Defense.

CAD, CAM, and CAE

CAD, CAM, and CAE (computer-aided design, computer-aided manufacturing, and computer-aided engineering) – sector has four major segments: mechanical computer-aided design and engineering (MCAD/MCAE); electronic design automation (EDA); architectural, engineering, and construction (AEC); and geographic information systems (GIS)/map.

3.7.5 Radio Frequency Identification (RFID)

A basic RFID system consist of three components namely an antenna or coil, a transceiver (with a decoder) and a transponder that is electronically programmed with unique information. The antenna emits radio signals to activate the tag and read and write data to it. Antennas are the conduits between the tag and the transceiver, which controls the system's data acquisition and communication.

RFID tags are categorised as either active or passive. Passive tags do not have an independent power supply, and must tap power from the host reader. Active tags come with their own battery power source to start up the tag operations. These wireless AIDC systems allow for non-contact reading and are effective in manufacturing and other hostile environments where bar code labels could not survive. RFID has established itself in a wide range of markets including livestock identification and automated vehicle identification (AVI) systems because of its ability to track moving objects.

Radio frequency identification (RFID) are embedded in objects, making them "intelligent" to external computers. These future tags will not only store information, but also contain a power source plus computing and communications functions. These capabilities will create a potential interface for enterprises to communicate and share information with an object throughout its life, enabling a myriad of applications that analyze, control or act on the object's state. RFID applications will include toll collection, fleet management, wearable computing and many others Gartner predicts that in the next 10 years, RFID technology will enjoy wide influence by enabling application innovations across the full product life cycle and value chain. Applications that combine RFID data with bar coding and other inventory, pricing and identification technologies will drive the innovation of in-store retail systems, warehouse management, transportation systems and after-sale tracking of product usage, it will eventually support full supply chain management and execution.

The industries that these applications can be used will affect, among others, the automotive, healthcare, pharmaceutical, manufacturing, warehousing, logistics and retail sector. If RFID is implemented it will allow greater accuracy of supply chain information, improved product quality and customer service. RFID therefore offers higher data storage capacities, higher identification speeds, and greater immediacy and accuracy of data collection.

3.7.6 Geomatics (GIS/GPS)

Geomatics consists of an integrated approach of measurement, analysis, and management of the descriptions and locations of Earth-based data, often termed spatial data. This is processed and manipulated with state-of-the-art information technology using computer software and hardware.

Applications in all disciplines which depend on spatial data, including environmental studies, planning, engineering, navigation, geology and geophysics, land development and land ownership

This technology is fundamental to all geoscience disciplines which use spatially related data, such as- Surveying, Geodesy, Remote Sensing & Photogrammetry, Cartography, Geographic Information Systems and Global Positioning Systems.

The requirements that are necessary for GIS to be implemented consist of a good set of infrastructure and utilising wireless technologies that are relatively cheap. An important requirement as well is information harmonization where information is integrated and key decisions can be made through this.

The industries that will benefit from Geomatics (particularly the GIS) are Automotive, cultural tourism, health industry as well as mining industries. These days, GIS is the backbone field of IT industry. The GIS applications within developing public utility systems, assessment of location and commercial circle analysis, 3D Virtual Reality, remote-reality (tourism) and education is becoming important today. GIS data will be used extensively via ultra-high-speed IPv6 Internet environments, shopping malls that utilize mobile terminals, apparel displays and sales using IT, model houses, electronic applications, electronic first aid, digitisation of education, etc.

The correct application of GIS and GPS increase efficiency of local government, contributes to revenue generation, and provides a host of intangible benefits that are meaningful to citizens, ultimately increasing the quality of life.

Geo-spatial technologies feature high as a cross cutting technology and are important within businesses operating in industries such as air, sea, land transport (automotive), tourism, health, mining, mapping, telecommunications and farming industries. It also forms an integral part of every aspect of business and government.

Due to explosion of mobile and satellite technology there is need for geospatial information examples include emergency and remote areas surveying. To prevent losing the major market share within Africa’s geo information sector there is a need to continue development into Geomatics applications. There are also many opportunities within software development and it can be exported to other countries.

3.7.7 Medical Technologies

Products in the high technology medical device sector include diagnostic and laboratory products, orthopedic products, surgical devices, cardiac rhythm management products, and diagnostic equipment, implantable cardiac defibrillators and sophisticated diagnostic imaging systems designed for highly specific markets.

The medical and dental equipment and supplies industry is one of the most exciting, dynamic, and innovative industries in the world. It takes advances from a number of different industries, such as microelectronics, telecommunications, advanced materials, biotechnology, pharmaceuticals, and health care services, and often harnesses its own technologies to the technologies of those industries, so that each one powerfully affects the direction of and innovation in medical devices.

Cutting Edge Applications

Devices that allow people with disabilities to operate machines and perform routine tasks is a hands-free instrument that is controlled by small muscle movements, such as a blink of an eye (electromyography), and brain activity (electroencephalography). Other devices include those controlled by tracking eye movements or by speech recognition technology.

Products well along in the development pipeline are about to make possible dramatically improved pacemakers, cochlear implants (for hearing), and medicine delivery systems. Looking further in the future, a toothbrush with a biosensing chip will check your blood sugar and bacteria levels while you're brushing your teeth and would come with a holder that would transmit information to a database containing your medical file.

A technology to prevent the fear of depleting ozone is skin surface mapping, a new imaging technology that can collect images of the skin surface over time and would enable people predisposed to melanoma to detect malignant moles as soon as they begin to develop.

Telemedicine

Telemedicine is an important combination of various technologies and consists of a collection of computers, communication networks, and video and specialised medical equipment that allows the potential to transmit high-quality medical images across a communication line. It enables a physician or specialist at one site to deliver health care or consult with another physician/medical personnel at a remote or rural site.

The areas that telemedicine can be applied to are a variety of medical areas including among others specialist areas like cardiology, dentistry, gynaecology, home care and primary care, dermatology, pathology, paediatric as well as vital signs monitoring.

In order to enable telemedicine there are a vast range of requirements that are needed first and foremost various technologies that make up the application telemedicine.

- Medical Devices
- Network Computing

- Video-conferencing
- Software Requirements
- Interface to database and other applications
- Technical support

Other requirements are funding, training, technical support as well as the correct infrastructure.

Should the telemedicine be implemented it has the potential to improve the standard of health care and provides effective and efficient medical intervention because almost all medical specialities can be practiced via telemedicine. The most studied applications concentrate on areas in which there is a shortage of experts in rural communities and in which the presence of visual data prevent telephone consultations from being effective.

Telemedicine is a high impacting solution because the government will be able to take advantage due to medicinal treatment which will be more freely available within remote areas but basic infrastructures, accessibility, network rollouts and human resources need to be addressed in order to take full potential of telemedicine.

3.7.8 Grid Computing

Grid Computing is an ambitious and exciting global effort to develop an environment in which individual users can access computers, databases and experimental facilities simply and transparently, without having to consider where those facilities are located. (Reality Grid, Engineering & Physical Sciences Research Council, 2001)

This has been identified by many global key players as an important technology trend. It includes the exploration of the potential of grid computing and related technologies which involves the incorporating of high bandwidth, computing, intelligent sensors, and large-scale databases into a pool of resources that are managed. This is made available to industry, scientists as well as the everyday individual because grid computing can be split between commercial and scientific purposes.

Once appropriate infrastructure is in place, a user will have access to a virtual computer that is reliable and adaptable to the user's needs. This virtual computer will consist of many diverse computing resources. But these individual resources will not be visible to the user. To reach this vision, there must be standards for Grid computing that will allow a secure and robust infrastructure to be built. Standards such as the Open Grid Services Architecture (OGSA) and various tools provide the necessary framework. Initially, businesses will build their own infrastructures (what we might call intra-grids), but over time, these grids will become interconnected.

Requirements of grid computing are the using of under utilised IT resources, providing a meaningful collaboration between knowledge workers and having a transparent and flexible development as well as management of the IT infrastructure. Cost effective high performance computing is also very important as well as a high bandwidth infrastructure. Other sets of basic facilities needed for Grid computing include security (single sign-on, authentication, authorisation, and secure data transfer) Resource Management, Data Management: secure and robust data movement and Information Services (directory services of available resources and their status)

- Application Programming Interfaces (APIs) to the above facilities
- C bindings (header files) needed to build and compile programs

The implications of grid computing are that it does have the ability to solve various needs like bioinformatics which requires a complex system of computational processing power as well as storage. (CSIR, 2004). Other areas where grid computing could be successfully used would be within the financial environment and healthcare where process capacity is optimised. Grid computing is very important within the research fields particularly biotechnology as well as other scientific research arenas.

Although Grid computing is still in its infancy it is clear that there are both advantages to be exploited and challenges to be faced. Software vendors in all markets need to reflect on what changes they need to make to their licensing schemes to enable Grid computing. Types of computer grids that occur are:

- Commercial grids - Grid formed for nonscientific, non-technical tasks across multiple enterprises to address a single, large-scale purpose. Grids can also be used within one enterprise. The term "grid" is sometimes misused to denote the related technologies of distributed and utility computing. Possible business impacts could be that new industry models could replace third-party intermediaries for large, multi-enterprise systems. (Jacob B, 2003)
- Computational grids - Grid that is focused on setting aside resources specifically for computing power. In this type of grid, most of the machines are high-performance servers.
- Scavenging grids - Most commonly used with large numbers of desktop machines. Machines are scavenged for available CPU cycles and other resources. Owners of the desktop machines are usually given control over when their resources are available to participate in the grid.
- Data grids – this grid is responsible for housing and providing access to data across multiple organizations. Users are not concerned with where this data is located as long as they have access to the data and would allow sharing of data, managing the data, and managing security issues such as who has access to what data.

Benefits of grid computing:

- Acceleration of time to results in assisting of the improvement to productivity and collaboration
  - can help solve problems that were previously unsolvable
- Enable collaboration and promote operational flexibility:
  - Bring together IT resources as well as people
  - Allow widely dispersed departments and businesses to create virtual organisations to share data and resources
- Efficiently scale to meet variable business demands
  - Create flexible, resilient operational infrastructures
  - Address rapid fluctuations in customer demands
  - Instantaneously access compute and data resources to "sense and respond" to needs
- Increase productivity
  - can help give end users uninhibited access to the computing, data and storage resources they need (when they need them)
  - can help equip employees to move easily through product design phases, research projects and more — faster than ever
  - can help you improve optimal utilization of computing capabilities
  - can help avoid common pitfalls of over-provisioning and incurring excess costs
  - can free IT organisations from the burden of administering disparate, non-integrated systems

3.7.9 Software Technologies

Computer software consists of the programs, routines, and symbolic languages that control the functioning of computer hardware and direct its operations. Simply software uses a computer-language program that operates by turning certain electronic pulses on and off within a computer.

Software remains one of the most innovative and fastest growing sectors of the global economy, Today the industry remains in the growth stage of its life cycle. Demand is increasing throughout the world. Consumption is greater in industrial countries, but is seeing faster growth rates in developing markets. South Africa particularly has a competitive advantage within the software sector where various innovative solutions and programmes have been developed locally and sold internationally.

Applications of Software Technology

The industry can be divided into three main sectors to include systems infrastructure software, applications, and programming tools.

Within these three main sectors are many sub-sectors:

- **Systems infrastructure software -** includes all programs that oversee and direct the internal operations of a computer system and enhance basic system functionality. The sector is divided into four areas:
- **System Level Software** – operating systems, utilities, and networking software.
- **System and Network Management Products** – System management software governs computing resources including tools to manage data storage and job scheduling. Network management software controls the components of the computing infrastructure, addressing network performance, configuration, and fault management.
- **Middleware** – software that allows shared use, or interoperability, of resources across interconnected, diverse computer systems.
- **Security software** – security software encompasses fire-wall, encryption, and antivirus software. This segment also includes authentication, authorisation, and administration products, which cover diverse applications such as intrusion detection, single sign-on software, and security management products.

The software outlook is very positive and all the segments will continue to grow rapidly as a result of explosive growth in E-commerce and internet applications and corporate enterprise computing.

Cutting Edge Technology

Other software technologies are also propelling the industry, such as three-dimensional (3-D) techniques, virtual reality, and voice recognition. Increasing computer memory and processor speeds are allowing the development of software technologies that depict more lifelike situations.

3.7.10 Open Source Software

This is software in which the program source code is openly shared with developers and users. Developers can customise programs, and these innovations, in turn, are shared within the programming community so that everyone learns from each other.

This software is developed, tested, or improved through public collaboration and distributed with the intention that it must be shared with others, ensuring further collaboration.

Benefits of Open Source Software:

- It has the potential to impact fundamentally on areas ranging from education to health, e-government and various spheres of business. OSS has emerged as a software model that is particularly viable in the developing world, providing local software developers with access to quality code generated by international experts; allowing users to escape from the cycle of ever-increasing international licensing fees and facilitating the development of systems that address localised needs.

- OSS costs can be a fraction of the cost of proprietary solutions and can provide an alternative model for developing countries because OSS and Linux can be freely copied without having to pay for the licenses. Although this is the case other costs like installation, support and training cannot be omitted

- There is a potential for fewer viruses in OSS, and when identified there is the potential to fix it quickly, resulting in higher quality and superior security due to the number of developers contributing to the software being a lot more.

Requirements for Open Source Software are training, having accessibility to utilise the Open Source Software, telecommunication, infrastructure as well as proper resources.

South Africa has a competitive advantage in software development and integration, resulting in a high position to take advantage of this solution as it enables accessibility to software at a low cost thereby having a skills based outcome. Open Source Software will also enable accessibility to developed software that has been utilised internationally, especially in aspects like development of security software as well as software for the banking and healthcare sector.

If conventional approaches are followed there is a possibility of having less of an opportunity to be able to afford investments into imported technologies, which are required to be a full participant in the global information society in the near future.

The areas of impact are sectors which include areas like education, health, business it will also enable an all inclusive information society. Open source software is a base technology so there is no real need to deal with specific applications. The solution is also reasonably cheap in comparison to the conservative means of obtaining software.

The government will benefit by allowing access to information, enabling a fully information inclusive society as well as improve skills and illiteracy within the country.

3.8 ICT Cross-Cutting in Various Sectors

ICT is becoming more of an enabling technology, providing essential support for the development of all technologies and industries. The convergence of ICT and the development of the networked economy, will result in the technology becoming more pervasive but less visible. There is solid economic growth potential in the convergence of ICT, but an even greater potential in its application in other industries. Some of the application areas linked with other industries is briefly listed below.

3.8.1 ICT for Metals and Minerals

Key areas of dependence on ICT consist of:

- Materials and material processing will rely on ICT to provide support capabilities for Modelling and simulation and large scale database for material attributes and performance

3.8.2 ICT for Biotechnology

Key areas of dependence on ICT consist of:

- Understanding human cognition and reasoning
- Transfers of knowledge about genetic programming
- Neuroscience application to artificial life
- Prosthetics (human machine integration)
- Bio-chips and cellular computing and memory
- Biosensors and imaging
- Imaging and visualization technologies
- Design, Modelling and Simulation
- Life Cycle Analysis
- Concurrent Engineering
- On-line production control
- Sensors (also with Life Sciences)
- Neural networks
- Image processing
- Dematerialisation
- Embed IT into products to reduce energy consumption and wasted resources

3.8.3 ICT for Mechatronics and Production Technologies

- Micromachines/nanotechnologies
- Sensors – biological and chemical
- Molecular manipulation techniques

3.8.4 ICTS for Transport Technologies

- Transport telematics and traffic control system
- Automatic operation of vehicles and driver support systems
- High business potential
- Improvement of efficiency and safety
- Substitution potential (communication for transport)

3.8.5 ICT for Tourism

- ICT in allowing communication
- ICT allowing interactivity
- Improvement of safety and security
- The potential for guests and consumers to conduct transactions utilizing information technology and telecommunication

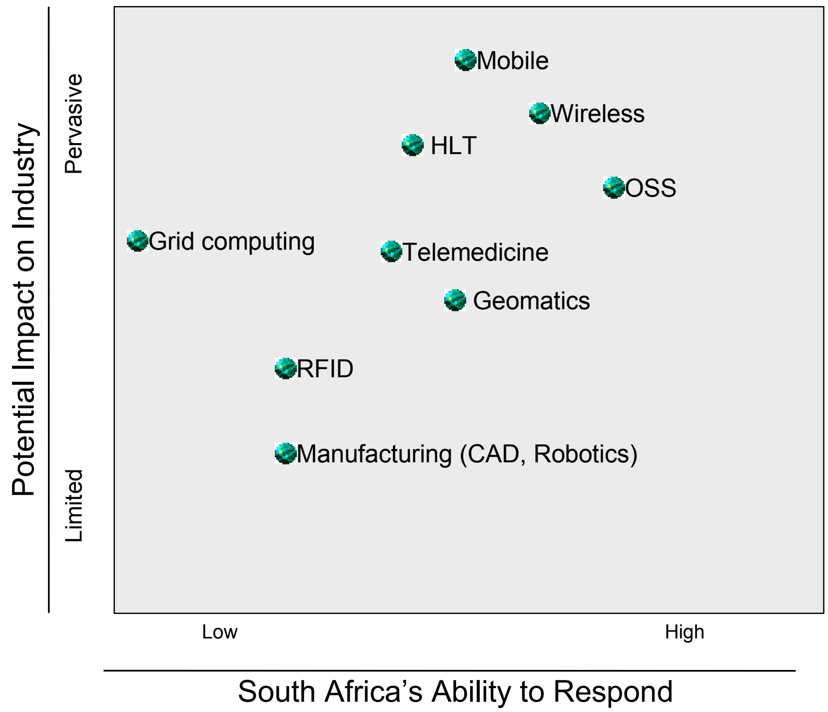
3.8.6 ICT for Cultural Industry

- ICT acting as an enabling technology creating an informed society and enabling communication within remote areas

3.9 Conclusion, and key considerations for the DTI

The following grid provides an illustrative summary of the technologies as well as technology areas that should be considered for possible further development. Their applicability as well as positioning within the South African context has been taken into consideration.

Figure 3: Impact analysis grid



The technology areas within the grid have been broken down one level lower and are summarised within the table below:

Table 6: Summary of emerging technologies

Technology Areas	Emerging technologies
Mobile technologies	Micro Fuel Cells, Smart phones, Location-aware services, Speech recognition, Alternative displays, "Haptic" technologies, New power sources, Wearable devices.
Wireless Telecommunications & Networking	Global System for Mobile Communication (GSM), General Packet Radio Service (GPRS), Enhanced Data GSM Environment (EDGE), Universal Mobile Telecommunications System (UMTS), Wireless Application Protocol (WAP), i-Mode, Ultrawideband, Fourth-Generation Wireless Technology, Bluetooth, VSAT
Human Language Technologies (HLT)	Speech recognition, speech synthesis, language translation technology, spoken language understanding technology
Manufacturing technologies	Robotics; CAD, CAM, and CAE
Grid computing	Mesh networks, Commercial grids, Computational grids, Scavenging grids, Data grids
Geomatics:	GIS, GPS

Further development and investment in mobile technologies and devices, wireless networks, human language technologies as well as Open Source Software should be considered as they are likely to have a high impact on South Africa and South Africa’s future competitive position. An important consideration with regards to the implementation of Open Source Software will be to ensure the Intellectual Property rights of the software should be made freely available to use. The requirements for these technologies are strong and also present significant opportunities to reduce South Africa’s socioeconomic deficit. RFID is under-hyped at present but is expected to be the next biggest trend within the ICT industry.

Mobile technology is important due to communications infrastructure being a basic requirement for all ICT initiatives. In the developing world, one of the reasons for the 'digital divide' is the lack of infrastructure and only wireless systems can effectively and efficiently address a gap like this. New connectivity technologies will enable more transparent and pervasive interaction with the environment.

Wireless networking is important for the delivery of telecommunication services, especially in rural areas. Landline and cellular telecom systems work well in metropolitan areas and smaller cities where subscribers are located in dense clusters that justify the high cost of equipment and licenses. However, connecting rural areas is a bigger challenge because subscribers are geographically dispersed, sparsely located, and economically weak therefore it is important to use wireless to leapfrog infrastructure bottlenecks. South Africa has a well-developed telecommunications infrastructure and has in the past been very innovative in terms of this industry so it would be extremely beneficial to exploit this strength even further. South Africa also has the advantage of having the best telecommunications infrastructure within Africa.

Human Language Technologies are an enabling conglomeration of technologies which can address the situation of information empowerment and allows people to interact with technology in a natural fashion. It undertakes to solve various issues like illiteracy, language barriers and disability. It also allows information to be provided in technologically under-utilised regions of a country. It can enable seamless human-computer interaction - both spoken and written – which improves efficiency and user-friendliness. HLT Bridges the gap between computer literacy and availability of information to all resulting in an all information inclusive society.

Open Source Software is important because South Africa has a competitive advantage in software development and in having the ability to get software that is available for free. It has the potential to impact fundamentally on areas ranging from education to health, e-government and various spheres of business. OSS has emerged as a software model that is particularly viable in the developing world, providing local software developers with access to quality code generated by international experts; allowing users to escape from the cycle of ever-increasing international licensing fees and facilitating the development of systems that address localised needs.

RFID technology will enjoy a wide influence within the next 10 years by enabling application innovations across the full product life cycle and value chain. Applications that combine RFID data with bar coding and other inventory, pricing and identification technologies will drive the innovation of in-store retail systems, warehouse management, transportation systems and after-sale tracking of product usage, it will eventually support full supply chain management and execution

The industries that these applications can be used will affect, among others, the automotive, healthcare, pharmaceutical, manufacturing, warehousing, logistics and retail sector. If RFID is implemented it will allow greater accuracy of supply chain information, improved product quality and customer service. RFID therefore offers higher data storage capacities, higher identification speeds, and greater immediacy and accuracy of data collection

Other technology areas that are likely to require further development are telemedicine, geomatics as well as technologies for manufacturing, specifically robotics. Their value in emerging countries has proven to have significant opportunities in the medium to long-term.

It is concluded that although South Africa is not a leader in ICT technologies but rather an adaptor, integrator, assembler and follower, the South African ICT sector does have various competitive advantages. These typically include a well developed telecommunications industries, established and competitive call centers, highly regarded capabilities in software development, e-learning and system integration. The industry is well positioned to exploit a number of emerging technologies, as identified in this report.

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THE TOURISM SECTOR

4 TECHNOLOGY DEVELOPMENT TRENDS OF THE TOURISM SECTOR

4.1 Summary

Tourism as a sector has grown and it is considered to be one of the largest global industries. It has a huge potential in job creation and in offering an opportunity to develop less favoured regions. Travel & Tourism is a labour-intensive activity and the majority of enterprises operating in tourism are Small Medium and Micro Enterprises. Travel and Tourism could be used as an activator for related industries due to investments and efforts that have been spent in infrastructure, plants and capital equipment from suppliers.

Tourism on an international basis is a major economic sector generating over $420 billion in tourism receipts, accounting for almost 4% of global GDP and sustaining close to 70 million jobs. It continues to be driven largely by affordable travel, especially by air, and travel opportunities opened up by new technologies as well as tourists looking for new experiences. Although the tourism industry is a major player internationally there are some constraints that have caused the sector to stagnate. These constraints include factors including economic downturn, terrorism, political unrest and the impact of the SARS virus which have had a great impact on travel in the past. The industry took a downturn but it appears to be slowly recovering again. Tourism as a major 21st century recreational/educational activity will continue to grow.

South Africa is renowned for its ecological splendour, cultural heritage and remarkable democratic transition. .These three components are the mainstay of international tourism. It is therefore a major contributor to the economy accounting for an average of 8.2% of the GDP. The WTTC has predicted that the tourism industry will continue to grow steadily through the years. According to WTO South Africa was ranked as 25th top tourism destination in 2000.

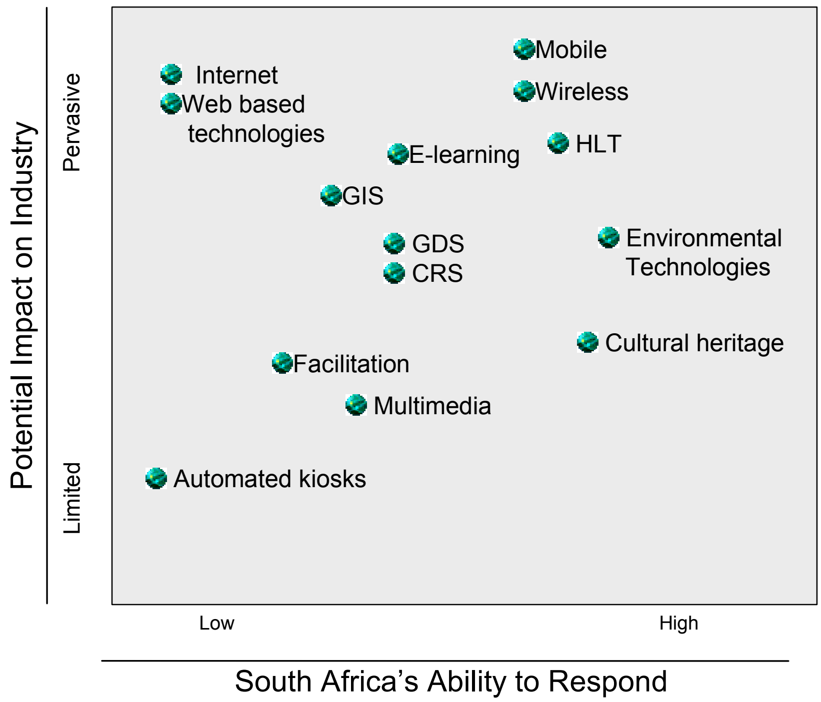
South Africa's constraints that could diminish its growth can be summarised with factors like lack of skills and knowledge, perceptions of crime and violence effecting the security, environmental degradation and currency volatility. In order to counteract these issues the government and various influential tourism bodies have identified the need for four sector objectives to be developed namely quality, product development, human resource development and marketing of the country. Within the international research a discovery was made that other countries have similar needs and concentrated efforts. Therefore when looking at policies as well as support programmes these issues were taken into consideration.

For South Africa to benefit from the tourism sector to its maximum it requires economic growth and sustainability. A clean, safe and healthy environment is necessary for sustainable tourism, in creating

growth marketing the country to the rest of the world is very important as well as participation from the broader population, constant development of the product i.e. South Africa, enable the provision of good services and a secure tourism destination.

In brief the important technologies can be summarised by means of the following grid:

Figure 4: Summary of technologies:



The technologies that can support these requirements and assist in ensuring sustainability and growth of the sector are ICT, environmental technologies (which include fuel efficiency, cleaner production processes), renewable resources and cultural heritage technologies. An important fact to keep in mind is that ICT is extremely prominent within the sector and is slowly changing the tourism environment as we know it today; obviously there is an understanding that the industry cannot be wholly driven by ICT but it does allow more flexibility and accessibility within travel and tourism.

Travel and Tourism are more labour intensive than technology orientated. Majority of the enterprises are SMME's. The tourism sector needs to be made sustainable therefore coordination, management and planning by government agencies are prerequisites for creating the modalities to sustain this tourism development, as well as to ensure that direct attention and explicit statements with regard to policies and future plans are developed.

Internet is playing an important role in tourism and could be a potential threat to the sector if not improved. The internet is one of the keys to globalisation and an increase in completing transactions as well as seeking information on various tourism destinations will be done utilising this medium.

From the technologies that have been identified it is quite clear that ICT is changing the current tourism environment and it allows more flexibility and accessibility within this particular industry. Although the tourism sector is not wholly driven by ICT, it is a prominent enabling technology. The tourism industry needs to use technology to improve productivity in reaching a broad and diverse customer base. To do this, it must be flexible and responsive to rapid change as well as be stable and responsible to its existing customer base and suppliers. It will be imperative to have strong relationships with customers and to use technology for frequent, interactive communication and targeted benefits.

Bloch, M et al identified three critical factors which need to be taken into consideration when designing an ICT enabled tourism landscape:

- Integration: each of the systems should be as integrated as possible and should represent a "one-stop" shopping experience. This will require standardisation among the different suppliers, in terms of data, functions and organisational procedures.

- Customisation: take advantage of technology to map as closely as possible the interests of the customer. As such, it should track each customer's profile, and present only the most relevant information. Each customer's interaction with the system should be used to increase the relevance of the relation

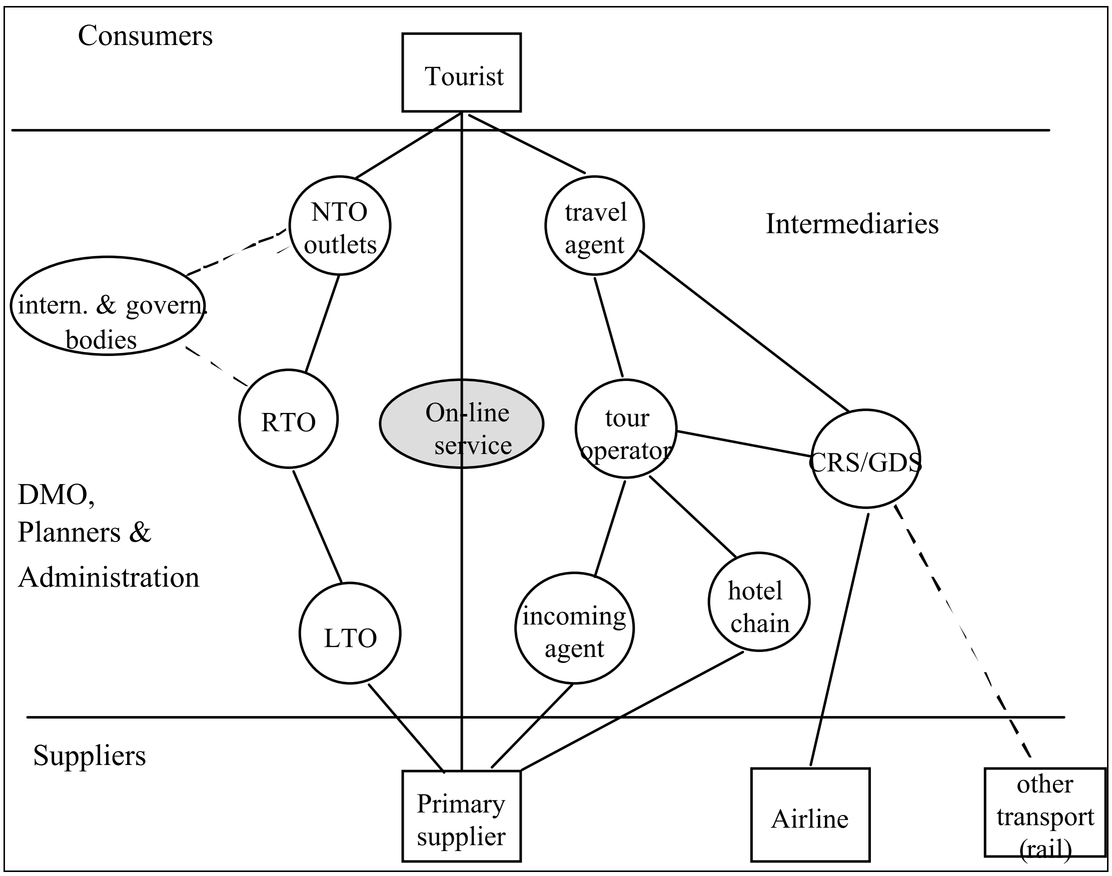
- Pro-activity: instead of simply waiting for customers to "drop-in", all of the ICT systems should strive to create travel needs. For example customers should be tempted to by a leisure travel package by presenting information on attractive areas and sites or by making available information relevant to professionals, they would be attracted by conferences in similar fields.

4.2 Context of Sector

4.2.1 Defining Tourism

Tourism is defined by the WTO (2002) as the activities of people traveling to and staying in places outside of their usual environment for not more than one year for leisure, business and other purposes not related to an activity that's remunerated within the visiting destination.

Figure 5: Typical structure of Tourism Industry



Source: Adopted from *Stylized view of the travel and tourism market (Werthner 1993; Werthner and Klein 1999)*

4.2.2 Tourism from a Global Perspective

Tourism is one of the largest global industries, it has a huge potential in job creation and in offering an opportunity to develop less favoured regions. Travel & Tourism is a labour-intensive activity and the majority of enterprises operating in tourism are Small Medium and Micro Enterprises. Travel and Tourism could be used as activator for related industries due to investments and efforts that have been spent in infrastructure, plants and capital equipment from suppliers.

Tourism on an international basis is a major economic sector generating over $420 billion in tourism receipts, accounting for almost 4% of global GDP and sustaining close to 70 million jobs. (Irish Tourism strategy, 2003). It continues to be driven largely by affordable travel, especially by air, and travel opportunities opened up by new technologies. Economic downturn, terrorism, the war in Iraq and the impact of the SARS virus has had a great impact on travel in the first half of 2003 where the industry took a downturn but it appears to be slowly recovering again. Tourism as a major 21st century recreational/educational activity will continue to grow.

The industry is projected to experience a doubling in the number of international arrivals over the next 20 years to almost 1.6 billion and it is being given increased weight and emphasis in the range of Government policies aimed at national as well as regional development.

In terms of technologies the application of new information and communication technologies has dramatically broadened people's access to information and travel opportunities. The result has been a transformation in the way people plan and book travel. Online travel sales, estimated at $30 billion in 2003, are projected to almost double over the next two years. Technologies already have a radical impact on holiday decision making by tourists and this trend will continue to escalate.

4.2.3 Global Drivers of Change

The tourism sector is a sector that has great variety and is changing on an ongoing basis, a summary of the main tourism global drivers of change is given below:

- Customers are now having shorter stays and the holidays are becoming fragmented.
- Clients are price sensitive and seek value for money or choose destinations offering two experiences for the price of one
- Ease of access to and from customers is on the rise
- Clients frequently make last minute bookings
- There is a greater demand for customised holidays and authentic experiences of the holiday destination

- Trend towards self development where the individual learns new skills, attends classes, and takes an interest in the arts, which has an obvious implication for tourism and holiday choices,
- Various attacks and occurrences on a global basis due to social instability has increased the need for security
- Increased competition from travel and tourism suppliers as well as demanders.
- Low cost airlines and cheaper alternatives of transportation
- Travellers are more mature and experienced
- Globalisation is on the increase.

Understanding the global drivers of change is important because it gives an indication of the type of markets that will be emerging within the tourism industry.

4.3 Tourism from a South African Perspective

South Africa is renowned for its ecological splendour, cultural heritage and remarkable democratic transition. .These three main components are the mainstay of international tourism. In contrast the tourism influx from the rest of Africa is largely structured around buying and selling. It is therefore a major contributor to the economy accounting for an average of 8.2% of the GDP. The WTTC has predicted that the tourism industry will continue to grow steadily through the years. According to WTO South Africa was ranked as 25th top tourism destination in 2000. Major international companies who have set up offices in South Africa include Mercure Accord Hotel (France), Sheraton Group (USA), Hilton (USA), Legacy hotels and resorts (USA) as well as Days Inn (USA).

4.3.1 South Africa’s position

South Africa’s tourism sector has many unique attributes to offer as a country. Placing South Africa’s position into the sector context will enable a better understanding of where South Africa is successful and where there are deficiencies. This will also enable the identification of possible technologies that can be used to support the gaps within the sector.

South Africa has some of the following strengths, weaknesses, opportunities and threats within the Travel and Tourism industry.

Table 7: South Africa's SWOT analysis

Strengths • Scenic beauty and landscape resources - beaches, mountains, deserts and bush and wild life • Offers variety of unique, world-class natural tourist attractions • Spectrum of high quality cultural and man-made attractions. • Good value for money • Infrastructure world class in Africa • Banking system world class • A well developed telecommunications infrastructure
Weaknesses • Not enough stakeholder coordination€ • There are limited budgets available • Marketing spend is fragmented and insufficient • High crime rates • Currency volatility • Airline under-capacitated over the peak season • A proper railway infrastructure that tourists can utilise • Limited tourism education, training and awareness
Opportunities • South Africa is a gateway to Africa • There is major room for innovative expansion and development • Improvement of existing and development of new attractions • Competitive long haul destinationGood telecommunications infrastructure that can potentially be exploited even more
Threats/barriers • Failing to improve perceptions of unacceptable levels of crime and violence. • HIV/Aids in hospitality industry • The benefits of tourism growth may not filter down visibly to grass roots • Broader population is not supporting the requirements for a safe, clean destination and need to market the area • Environmental degradation • Lack of education and training of travel and tourism support staff

For South Africa to maximize on the benefits of tourism, the sector has to be sustainable in terms of ensuring that the environment is clean and secure and growth has to be created. The government and various tourism bodies understand the aftermath of creating growth and a sustainable environment, for this purpose 4 specific objectives need to be met to deem this a possibility namely **quality** of the products and provision of services, **development of the product, marketing** to the rest of the world supported by the whole populations participation through **human resource development.**

4.4 Role of Technology in Tourism Development

Technologies could be utilised within the tourism industry to improve the sector, to develop and improve productivity within the sector as well as allow the ability to reach a broad and diverse customer base nationally as well as internationally. The technologies require a focus on flexibility and ability to be responsive to rapid change but parallel to this, be stable and responsible to the existing customer base and suppliers.

Technologies that have the potential to assist in meeting the overall objectives are briefly mentioned.

***Technologies for sector sustainability*.**

After speaking to global and local experts, environmental technology will continue to be a key growth area due to the deteriorating environmental conditions, increased awareness of environmental issues, and investor recognition of the urgent need for environmental protection worldwide. The environment is a core product to offer tourists and should this be destroyed a decline within the tourism sector could be the resulting effect.

Technologies for growth of the sector

In order for the sector to grow the four objectives are taken into consideration specifically allowing the participation of an all inclusive information society by means of human resource development and skills transfer, a secure environment, enabling a good quality service, developing the product further and being able to do marketing to the rest of the world.

For participation the type of technologies that are important are of the technologies that provide accessibility and the ability to communicate. These technologies include mobile devices, wireless networking as well as Human Language Technologies which will give the society a platform to be an all information inclusive society and a foundation for communication.

In terms of service delivery basic technologies like good booking systems, proper accommodation, energy, clean water and sufficient transport facilities are necessary. Training is also pertinent to service delivery and therefore technologies like e-learning and training are necessary.

Security is an important aspect especially due to aspects referring to the global political instability that is occurring, as a result sufficient passenger screenings and secure websites by means of encryption are extremely necessary.

Within areas of product development technologies that restore and preserve cultural heritage are important because there is a threat of degradation of cultural heritage within the environment as well as vulnerability of cultural heritage to hazards and prevention measures. The preservation of cultural heritage will enable social and economic integration of the cultural heritage, cultural heritage in urban areas, and preserving the great South African success story.

Finally technologies that provide a good foundation to be able to market South Africa to the world are important because this will ensure high visibility to the international as well as domestic tourism market and also provide awareness to the benefits of the product.

4.5 Identification of Technologies to Meet Sector Requirement

The following section provides a summary of the type of technologies that are important to ensure that the tourism sector is sustainable, has growth and meets all of the required objectives which were mentioned above

4.5.1 Environmental Technologies

An environmental technology is a technology that advances sustainable development by reducing risk, enhancing cost effectiveness, improving process efficiency, and creating products and processes that are environmentally beneficial or benign. The word "technology" includes hardware, software, systems, and services.

The categories of environmental technologies:

Avoidance: Avoidance technologies avoid the production of environmentally hazardous substances or alter human activities in ways that minimize damage to the environment.

Monitoring and assessment: Monitoring and assessment technologies are used to establish and monitor the condition of the environment, including releases of pollutants and other natural or anthropogenic materials of a harmful nature.

Control: Control technologies render hazardous substances harmless before they enter the environment.

Remediation and restoration: Remediation technologies are those that render harmful or hazardous substances harmless after they enter the environment. Restoration technologies embody methods designed to improve ecosystems that have declined due to naturally induced or anthropogenic effects.

Growth sectors include those fields that use new environmentally clean technologies to combat global pollution or that provide energy-saving solutions in face of declining energy and mineral resources. Examples of such fields are wind power and bioenergy, both of which offer a clean and renewable form of energy production. Recycling and waste management are also growing in importance. For example, using waste for energy generation is a viable option, as there are a host of new compact techniques for burning and gasifying mixed waste. Innovative technologies that combine waste management and energy production have been developed to meet the needs of sparsely populated areas and relatively small waste quantities. Other interesting growth sectors are air pollution control, water and waste treatment and the development of renewable natural resources and recyclable and reusable materials. The most promising technologies can be used to develop existing processes and respond to future changes in environmental regulations, thereby creating new opportunities in business-to-business markets as well as ensure sustainability.

4.5.2 Technologies to Restore Cultural Heritage

There are many opportunities for the development and research into this area for cultural heritage. The idea from cultural heritage is widening from a single monument to landscape to a closer integration with the environment as a whole. It is important that there is a methodology to assess the architecture within the urban setting and also evaluate the management techniques by qualitative and quantitative assessment methods. The requirements for cultural heritage are Multi pollutant situation needs to be studied to get an idea of the mechanisms and rate of processes. Controlling the environment and assessing risk and monitoring systems, establish acceptable/threshold values of corrosion rates to materials of cultural heritage and transform to acceptable levels of pollution, develop the development of methodologies and improve public awareness.

There is an increased emphasis on non-destructive test methods, focus is on these techniques.

Overview of available techniques

Radiography

The screening of elements with gamma radiation reveals hidden discontinuities like reinforcement, holes, anchors or cracks. Accessibility on both sides is a necessary condition. Only the most powerful equipment is usable for masonry or concrete because of the attenuation of the gamma rays. This requires severe safety regulations. As such the technique is mainly valid for controlled circumstances in the laboratory.

Infrared thermography

A crack is a local discontinuity that hinders the conduction of heat. By heating the wall locally, a thermal camera is able to bring into vision these discontinuities. The method gives good results in case of large cracks close to the surface. Therefore, the method could work in case of rendering or stucco that is coming loose.

(Ultra) sonic research

This NDT-technique uses sonic waves from the audible spectrum (sonic) of the higher frequency range (ultrasonic). A longitudinal sonic wave is send through the material. Since the wave reflects on all kind of heterogeneities the analysis of the reflected waves provides a confusing image. Therefore most of the time the transition speed is recorded. The speed of the sound wave depends upon the materials' properties. Since internal loss of coherence forces the sound to follow a longer way or to pass through a layer of air, the transition time increases.

The investigated structure needs to be accessible from both sides. Furthermore, the wave attenuates quite fast. Acoustic tomography is an enhanced version of the same technique. Using a suitable combination algorithm, (ultra) sonic measurements can detect and locate the internal crack pattern. The technique proves to be a good control method for the reparation.

Soil penetration radar

This technique is entering the field of non-destructive testing of buildings. The method as such has been taken from soil investigation. The method is developed in order to detect borders or transitions between different layers. This way the technique can be adapted to the needs of non-destructive testing of masonry structures. The principle of the method is relatively simple. An antenna sends a radar wave into the material and the reflected signal is analysed. Internal cracks or transitions between different materials reflect the radar wave. Knowing the speed of the waves, the depth of the transition can be calculated. By moving the transmitter, a surface can be scanned. The processed signals are called a profile. The shape and the position of the reflections inform the researcher about the inner state of the structure antenna signal time

Geo-electrical measurements

Two subsequent doctoral research programs have developed this technique into a practical applicable instrument. The first doctoral research (Janssens, 1993) calibrated the methodology for different configurations of potential and current electrodes. The subsequent research (Venderickx, 2000) focused on the influence of geometrical boundaries and the influence of physical parameters (humidity and soluble salts).

Principle

The method is, again, adapted from a geophysical research method. Two current probes induce an electrical current in the material; the potential difference is measured by the potential probes. Depending on the geometry of the investigated structure a different probe configuration can be used

Additional technologies:

The types of technologies that fall under cultural heritage are explained below:

Interactive and intelligent systems to preserve cultural heritage and environment

- Great intelligence systems, technologies for learning and knowledge management
- Communication and computing infrastructures like wireless communication systems and networks as well as audiovisual applications

Intelligent materials and bio-technologies to safeguard cultural heritage

- Technologies that optimise applications of field of cultural heritage safeguarding
- Technologies in damage prevention like energy dissipation, polymer matrix composites, fibre reinforced silicate matrix composites.
- New composite materials for conservation
- Biocontrol of wood decaying

Nano and micro-technologies in technological research of historic materials, structures and technologies

- Micro technologies in historic materials, structures and technologies for example X-ray microscopy, neutron microscopy, radioscopy and laser technologies
- Use of nanotechnologies for testing historic materials e.g. nano-indentation of natural fibres and nano-scrach testing

The above technologies mentioned are quite advanced but there are possibilities for re-introducing traditional technologies that ensure more of a rational use of natural resources for example timber and wood based materials and products in construction and housing as well as stabilising and solidifying unburned clay for the construction and housing.

4.5.3 Information and Communication Technologies

The ICT applications are very similar in all the broad areas of tourism. The majority of the focus is on quality improvement and strategic management of the tourism resource with increasing investment in new products and services that are possible through the use of ICT (SAITIS, 2002). ICT represents truly powerful tools to improve both the lives of people and the competitiveness of countries. In particular, in their economic applications, ICT can dramatically enhance the capacity of enterprises of developing countries to compete with their products and services on the global market. Key technologies being deployed in the industry include multi-media (for promoting tourism capabilities) and Business to Business and Business to Consumer e-commerce (for tourism marketing and reservations).

The use of ICT in the future will be on an increase and it becomes a very important part of the tourism experience, therefore in order to be a globally competitive market substantial attention needs to be placed on the increasingly use of ICT within the tourism sector in order to ensure remaining in the competitive field. One of our competitive advantages is that South Africa is considered as being great value for money as a product, South Africa also has a well advanced telecommunication industry so this needs to be utilised to its maximum capacity in terms of ICT technologies.

The table below indicates very clearly examples of technologies and applications that are used within each area of the tourism sector value chain.

Table 8: Technology support within tourism value chain

Areas within Value Chain	Technology
1. Information collection	• Heterogeneous dynamic distributed networks for data collection • Multimedia object management • Co-operative processes • Workflow procedures • Common rules and interoperability protocols
2. Information organisation, interoperable heterogeneous system architecture harmonisation standardisation	• Distributed heterogeneous open systems architectures • Database Federation, • Data, communication protocols, • component reusability standardisation and harmonisation • Metadata, EDI • Innovative Business Processes (Virtual Enterprise & partnership mechanisms)
3. Information processing Information filtering and aggregation and product creation through aggregation of heterogeneous products	• MM production • Workflow procedures between different organisations • Classification procedures • Optimisation of value creation process • Product creation and aggregation • Contents creation, preparation and structuring • User modelling • Intelligent Agents for direct marketing and user profiling • Managing information overload; filtering methods (passive; custom...)
4. Information presentation, new trend in user/interface	• Interface issues: filtering, user modelling • Intelligent agents • Computer Human Interaction • Automatic translation • Push technologies, customised filtering for more acceptance of push • Filtering multilingual documents and multilingual data mining • Customer -targeted information views • Natural language processing • Multi media • SGML/XML and related editors

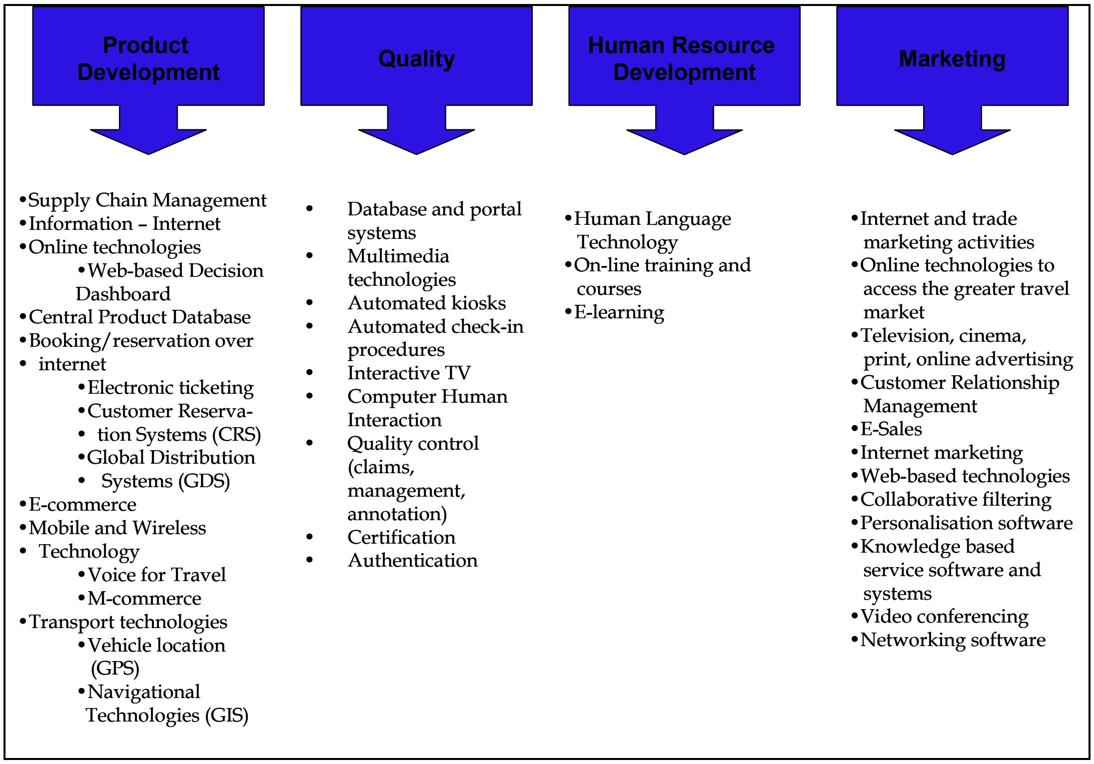
5. New marketing - advertising techniques	• Webcasting • Push technologies • Client - Networking • User Models • Intelligent Agents for direct marketing and customer profiling • Multimedia , Virtual Reality
6. Monitoring , planning, forecast services creation) **Yield and capacity management (at local/regional and at corporate ; at enterprise level for optimising product utilisation)**	• Artificial Intelligence: expert systems for planning ; intelligent agents for data mining; neural networks • Very Large Databases and distributed systems; metadata • Statistics: trend, casual, demand/product gap analysis • Monitoring , planning, forecasting techniques • Optimisation of value creation process • Modelling and Simulation • Decision Support Systems • Remote and satellite sensing, GNSS • Operation research • Forecasting techniques
7. Information access and distribution Peripherals, networks and distribution channels for mobile ubiquitous user access	• Networks • Satellite, GNSS, GSM, UMTS • Portable devices, user profiling • kiosks smart cards • Mobile access - info mobility • Short GSM message • Interfaces with GDS • Interactive TV • Phone voice systems
8. Booking and reservation payment systems	• Secure transactions • Encryption • Smart Cards • Electronic transactions • Digital signatures, electronic authentication • E-cash fund transfer, micro payments
9. Managing multimedia content and training systems	• Multimedia objects • Virtual reality • Environment for interactive electronic publishing • Distribute content packaging and • User-specific contents customisation • Methods for creating and structuring contents • Content production suitable for different kind of usage, of interfaces, of peripherals, of users • Dynamic reshape of digital contents • Semantic-based agents • Education and training: systems • Personalized interactive tutoring systems • Tutorials design tools

Source: Adopted from information society related RTD & tourism (http://knite.lii.unitn.it/)

The table indicates the prominent value that ICT has created within the tourism sector and all of the areas within the value chain providing a complete service and developing the product.

After interviewing local and international experts, the following diagram provides a summary breakdown of the types of ICT technologies that would be beneficial within the broader areas of the objectives which have been identified within the report.

Figure 6: Division of technologies to meet objectives



The above diagram shows all the type of ICT technologies that will have The important technologies that will have an impact on the tourism sector are described within the following section.following section highlights the important ICT technologies which will have the most relevance within the South African tourism sector:

Internet

The internet is an interactive information-supplying medium which is user friendly and gives enormous information of all kind related to travel and other aspects. Whether it's used for research or for purchase, the Internet is an increasingly valuable tool for travellers. According to an April 2003 My AvantGo survey of more than 1,000 individuals, 52 percent purchased more than half of their travel needs online, with 29 percent indicating that they made all their travel arrangements on the Web, 30 percent plan to increase their online travel purchases over the coming year. (Greenspan R, 2003)

These statistics show that the internet is extremely important because the internet provides an opportunity to provide up-to-the-minute information and allows control over the information presented through ownership.

'Public' ownership of the internet means that people can promote almost any message that they want. Global connectivity of businesses and customers reduces old barriers in space and time and enables new value constellations that are richer in form than the traditional value chain

It increases public awareness globally and relatively inexpensively, trying to achieve the type of exposure using traditional media would be prohibitively expensive for most organisations because it reduces the need for costly leaflet/brochure reprints, particularly those incorporating features such as timetables, events and accommodation listings, multiple languages and contact details.

It allows the re-use of panel, leaflet and/or visitor centre artwork. This artwork can simply form a backdrop for textual information, or may be the basis for more complex animations and interactive games and puzzles. It also enables rationalisation of information, this appeals to the modern consumer behaviour which favours the one-stop-shop and customisation.

Customer Reservation Systems

CRS systems are now virtually indispensable to airlines because they enable their revenue streams to be maximized by efficient inventory control (airline's stock of passenger seats that is available for sale). However, these days, hotel and car hiring companies by renting the service from the airline companies are also employed these systems. (Mekonnen & Egziabher, 2001)

The technology works by using computers of special kind and telephone lines. The travel agent is connected on line to the central host computer system or CRS. The host computer is almost always a mainframe with massive database attached. The mainframe host polls each travel agent terminal every second or so, to see if it has any messages to send. In this system it is possible that airliners, Hotels and car rental companies can talk to the travel agent and vice versa. This system contributes to a great extent in increasing sales volume and giving precise information on the availability and selling the products efficiently ensuring substantial profit gain.

GDS (Global Distribution Systems)

GDSs are systems which distribute reservation and information services to sales outlets around the world. Unlike the CRS's used solely by an airline or hotel chain, GDS distribute more than one CRS to users who are usually travel agents. These are 4 main GDS's namely Amadeus, Galileo, Sabre and World Span. These worlds leading GDSs are switches or simply computers that are connected on the one side to many different supplier systems and on the other side to many end users.

The end users of switch comprise travel agents with a single reservation system to support the sale of airline seats and related travel products such as hotel-and car hire, via a single computer terminal, usually a Personal Computer (Inkpen pp.107).

GDS's require large investment because they are extremely large computer systems which link several airlines and travel principals into a complex network of PCs, telecommunications and large main frame computers. GDS are a macro version of CRSs with a specialized and improved information technology for the distribution of Travel products.

Geographic Information Systems (GIS)

GIS is a valuable tool for managing, analysing, and displaying large volumes of diverse data pertinent to many local and regional planning activities. Due to the complex nature of tourism planning issues the potential of GIS to resolve issues like these are acknowledged GIS applications in tourism have been confined to recreational facility inventory, tourism based land management, visitor assessment and recreation wildlife conflict.

There is lack of databases and inconsistencies in data making its applications limited. There is little site specific information about sources of visitor's origin and destination, travel motivation, spatial patterns of recreation and tourism use and suitability of sites for tourism development

Table 9: Tourism related issues and GIS applications

Problem	**GIS Application**
Benchmark/database	Systematic inventory of tourism resources
Environmental management	Facilitating monitoring of specific indicators
Conflicts	Mapping recreational conflicts recreational wildlife and user conflict
Tourism behaviour	Wilderness perceptions/predictions
Carrying capacity	Identify suitable locations for tourism/recreation development Simulating and modelling spatial outcomes of proposed tourism development
Data integration	Integrating socio-economic and environmental datasets within a given spatial unit
Development control and directions	Decision support systems

Source: *Adopted from GIS applications in tourism planning*

Mobile and wireless networks

One of the things helping developing countries to rapidly close the communications gap is the mobile phone. Communications infrastructure is a basic requirement for all initiatives that require the development of an all information inclusive society. In the developing world, one of the reasons for the 'digital divide' is the lack of infrastructure and only wireless systems can effectively and efficiently address a gap like this. New connectivity technologies will enable more transparent and pervasive interaction with the environment

The mobile world is going to change massively. People will start using mobile technology to access the net, simply because it will be faster. Its proven technology and it makes true wireless networking a distinct possibility. It will also assist in the tourism industry being a global market and customers all over the world will be able to have accessibility to South Africa.

The telecommunications industry is changing on a continuous basis. New technology is creating opportunities, and telecom companies are racing to keep up. The convergence of the Internet, cellular phones and PCs, plus growing access options through wireless, fiber optic, satellite and DSL, promise a constantly connected global society. Communications technology is tearing down barriers between countries, cultures and communities

Facilitation

Facilitation is one important aspect of enhancing tourism business. Facilitation includes, issuing of visa, customs clearing and immigration check in ports. Lack of appropriate management in giving fast and efficient service to tourists in this area will deter the tourist flow substantially. Development has come about in using electronic medium for facilitation purpose.

A good example of using this facilitation is Australia which has developed the ‘Automated Visa Application system’ called ETAS (Electronic Travel Authority System).

This system works with three inter-linked functions, each of which is supported by computers that are located in different parts of the world. (i) A front-end ETA application processing system supported by travel agents chosen GDS or CRS. (ii) An international data collection and routing system based on a SITA computer located in Atlanta, and (iii) a data base look-up and electronic funds transfer system supported by the Australian Immigration Department’s computer in Sydney (Inkpen, pp 52).

Based on these networks the electronic visa, where nothing will be put on the applicant’s passport will be processed for the traveler by an authorized travel agent. The travel agent feeds its computer with all details of the traveler and transmits to Australia where the details appear on the Australia Immigration Department computer.

The visitor will be checked into the immigration computer at Sydney Airport just by simply entering a passport number.

Multimedia technologies

Refers to the joining of more than one medium in a program like audio, video, graphics, animation and computer data used together for a programme. One of the means that multimedia technologies can be utilised to improve quality is to accommodate the preservation and management of a country's national heritage.

As the numbers and complexity of structures and other resources grow, the use of information technologies becomes increasingly important. Developments in multimedia systems resulted in the creation of interesting and innovative applications that aim to the preservation and restoration of culture heritage.

Advances in Information technologies that accommodate this direction in a more affordable way are the GIS (Geographic Information Systems), systems that are used to store, manage and display geographically referenced data, together with GPS (Geographic Positioning Systems).

Digital photogrammetry is a computerised process in which photographic images are converted to precise measurements and this can perfectly and economically accommodate the presentation or interpretation of sites and structures.

Multimedia DBMS (Data Base Management Systems) permit the recording and management of large volumes of data in different forms like text, images, video and they can keep any necessary repository of culture heritage data. Multimedia offers the means of recording, storing and presenting more accurate culture heritage information since text can be enhanced with maps, photographs, videos etc.

Multimedia technologies also give a new meaning in training and educational material that can assist the training of culture heritage professionals Web technologies can act as a vehicle to deliver culture heritage information to any user around the globe.

Automated kiosks and check in procedures

Kiosks that are automated and allow the person to perform transactions. Automated kiosk can serve user's information needs in a user-friendly and personal way

Video conferencing

There is the use of Information technology called video conferencing which allow the possibility of exchanging data and holding discussions in any part of the world without leaving the office. In brief the technology is possible by using computers to enable people to meet each other. Television screens linked by high-speed telecommunication lines are used to hold discussion and assess the impact of conversation on participants. Live transfer of data and discussions are possible. Coupled with non-verbal communication where people look at each other's reaction, video conferencing creates virtual togetherness.

Video Conferencing allows the opportunity to discuss new development plan, a research problem or a research finding. This medium of communication reduces cost in time and cost of travel, because participants don't need to travel to meet each other face to face.

Personalisation software

It is a form of data mining. It has the philosophy that people's lives are busy and there is a want for other people to look after their needs. This type of software tracks and monitors preferences and purchasing behaviours of consumers therefore it can customise products/services based on needs as well as preferences and perform direct marketing accordingly.

Electronic payment

It enables electronic transactions. It has 5 impacts on business operations namely: 1) The complicated buying payment process is simplified and there is a bypass of intermediaries. 2) It helps in monitoring and tracking causal relationships between the effect of advertising and purchasing patterns 3) It facilitates the efforts required for niche marketing and narrow casting 4) it lowers the entry barriers into the tourism industry and in doing so increases competition, lastly it expands the competitive capability of small organisations to enlarge their business.

Human Language Technologies

These consist of technologies that use knowledge about spoken and written language and about developing computer software to recognize, analyse, interpret and generate language (Lackwood and Joscelyne 2003). Technologies that are used here are speech recognition, speech synthesis, language translation technology and spoken language.

This technology is an enabling technology which can address the situation of information empowerment and allows people to interact with technology in a natural fashion. It undertakes to solve various issues like illiteracy, language barriers and disability. It also allows information to be provided in technologically underutilised regions of the country (CSIR, 2004). It also enables seamless human-computer interaction - both spoken and written – which improves efficiency and user-friendliness.

HLT Bridges the gap between computer literacy and availability of information to all. The speech technology can be utilised for interaction with various databases of information and it can be accessed through various means like telephone, information kiosks and the internet.

In terms of industry linkages it has the potential to facilitate government service delivery, stimulate economic activity, enhance cultural tourism and improve the cultural industries by having an accessible multilingual technology.

Resource development is a very important requirement as well as additional research and development. The deployment of the various technologies is necessary as well as having a storage capacity for a massive information load.

E-learning

The uses of technology to manage, design, deliver, select, transact, coach, support and extend learning (of all kinds). (Elliott Masie, 2001) The use of network technology to create, deliver, foster, support learning activities independent of time and space',

The main components of an e-Learning system comprise:

- Learning Management Systems (LMS)
- Learning Support System (LSS)
- Learning Content Management Systems (LCMS)

Establishing an e-Learning infrastructure for education and training is a key to creating a new information and knowledge-based society. An e-Learning programme at a national level should involve both public and private sectors. It should involve education and training institutions as well as the relevant social, industrial and economic players.

E-Learning lays a foundation for knowledge-based societies. It should bridge the generation gap. New generations grow-up without fear of computers or communications. ICT becomes a normal tool of day-to-day lives.

Benefits of E-Learning include enabling the realisation of the following benefits:

Decreased cost of training

- Ability to offer life long training to their employees
- Ability to measure and record the Learners performance
- Reduced travel and related costs
- Enhanced employee retention of knowledge
- Individualized training through the accommodation of a variety of learning styles

4.6 Technology Positioning Analysis

The following table provides an overview of the most important technologies within the tourism field that will have the ability to meet the various sector objectives within the country. It highlights sector objectives, the possible technologies as well as the requirements that are needed in order for the technologies to be deemed a success.

Table 10: Technology positioning analysis

Technology	**Technology requirements**	**Position and impact in South Africa with regards to technology and requirements**
Geomatics (GIS)	Infrastructure Wireless networks relatively cheap Integration of information Training	South Africa's position is medium because of the need to improve the infrastructure and due to slow network rollouts but it will enable the creation of information integration and harmonisation resulting in a medium impact of technology on South Africa.
Mobile and Wireless networking technologies	Affordable technology Infrastructure Regulation around the infrastructure Wireless enabled access points Security of information	South Africa has strong telecommunication infrastructure and fixed line technologies installation is relatively inexpensive as well as rapid. The costs to maintain this technology as well as the technical expertise needed for maintenance of the equipment is quite economical. If implemented the impact of technology will be high because it will enable easier accessibility and South Africa has a strong position in terms of wireless technologies. This in turn will enable South Africa to be globally connected and accessible as well as globally competitive within the tourism industry.
Internet	Telecommunication infrastructure High bandwidth Security and encryption for safe payments on line Networks Access points Content Provision	South Africa's position is weak due to the technology being causing unreliability, slow internet accessibility, the technology is expensive and security is an issue. If implemented correctly the impact of the technology will be strong allowing a supply of information on world leading and emerging tourist destinations, communication, accessibility, and enablement of a fully informed society. It also enables the completion of holiday transactions online from all over the globe using plastic money.

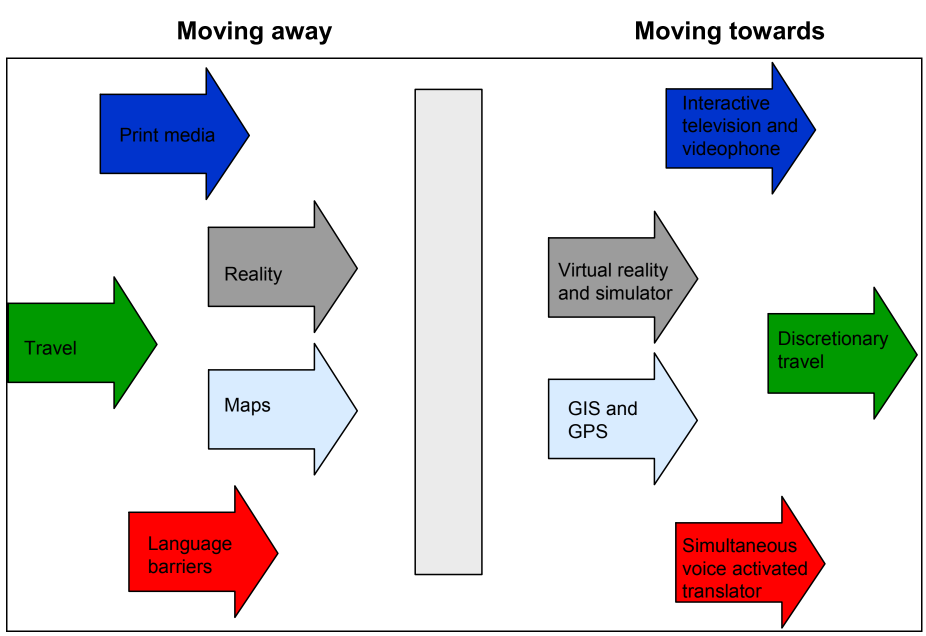
Multimedia technologies	Infrastructure Content provision Integration of software providers and content providers Telecommunications Access points Resource development	South Africa's position is low in terms of multimedia technologies due to a need for Improvement of internet access. But it is implemented it will enable South Africa to be more rapidly marketed using online marketing and assisting in improving the tourism sector.
Automated kiosks	Security Networking Wireless technology Content provision Infrastructure Access points	Allows the ability for tourists to get information readily at strategic tourism points but there is a need for physical security at the kiosks.
Human Language Technologies	Innovation Infrastructure Investment Resource development	SA has already invested considerable amount of money into this area and there are strong system integrators. The technology has a strong impact on South Africa because we have the advantage of the 11 languages that need to be addressed enabling a positive effect on bridging the skills gap as well as overcoming the illiteracy issue.
E-learning	Infrastructure Networks Investment Multiple sources of devices i.e. TV, Radio, interactive TV's	Incorrectly positioned value chain focused on educator rather than learner is causing the positioning to be medium but it will have a strong impact if the focus of the value chain is correct, it will enable accessibility to education and literacy as well as job creation.

CRM	Back Office Integration (BOI) Framework Business Process Re-Engineering Security Framework including authentication over all channels Standards	CRM is a focus on the customer. The tourist nowadays has a focus on living the experience as was mentioned in the drivers of change. By improving the experience of the tourist it will increase the likelihood of returning to South Africa.
Web based technologies	Innovation Infrastructure Investment Resource development	Improve internet access Strength in software development

4.7 Conclusions of Technology Trends in Tourism

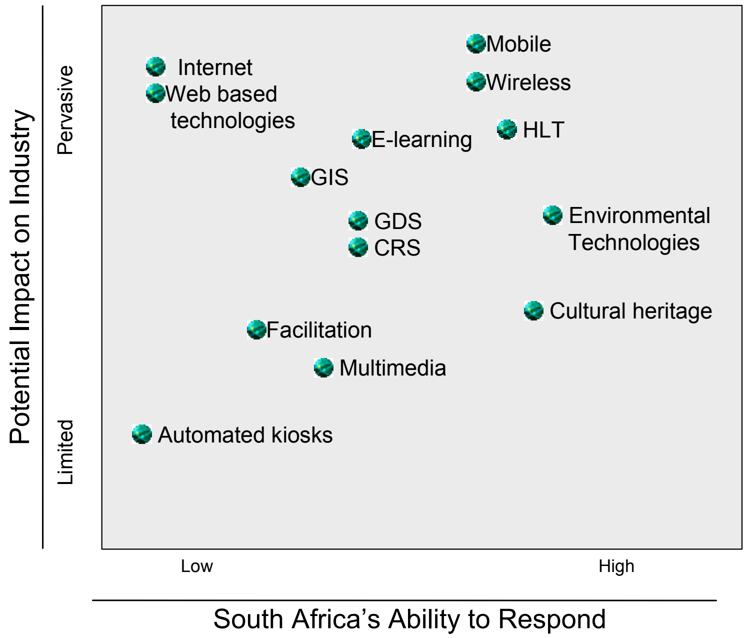
This tourism environment is shifting towards a greater emphasis on ICT and the traditional means of doing things for instance travelling, print media and maps will be transformed into more orchestrating technologies e.g. of these include interactive televisions, GIS and GPS as well as discretionary travel. These types of changes are summarised in figure 3 below which demonstrates the technologies and methods used now and the technologies that could change the tourism industry as we know it today.

Figure 7: Technology changes



This being the case with the changing tourism environment the grid below highlights the important technologies that need to be considered for future development in order to ensure that South Africa stays globally competitive and in touch with the rest of the countries as an emerging tourism destination.

Figure 8: Impact analysis grid



There are a wide variety of technologies to support the tourism industry but when focusing on South Africa's national campaign to reach objectives such as creation of jobs, improvement of quality of life, to have economical growth as well as to be an all inclusive information society, the table above summarises the key supporting technologies which are necessary to sustain and grow the industry encompassing the four sector specific objectives namely product development, quality, human resource development and marketing.

The technologies which will enable sustainability and further development of the sector are mobile and wireless technologies enabling areas like m-commerce, accessibility and communication. Human Language Technologies that are a combination of various technologies placed together allowing the bridging of language barriers. E-learning, web based technologies and GIS are also important with a medium positioning but a strong relative impact on the sector. An important technology for the tourism sector is the internet because this will enable all transactions and online marketing to take place allowing easier accessibility to information on a global as well as on a national basis, but the infrastructure and network needs a vast improvement.

Travel and Tourism are more labour intensive than technology orientated. Majority of the enterprises are SMME's. The tourism sector needs to be made sustainable therefore coordination, management and planning by government agencies are prerequisites for creating the modalities to sustain this tourism development, as well as to ensure that direct attention and explicit statements with regard to policies and future plans are developed.

Internet is playing an important role in tourism and could be a potential threat to the sector if not improved. The internet is one of the keys to globalisation and an increase in completing transactions as well as seeking information on various tourism destinations will be done utilising this medium.

From the technologies that have been identified it is quite clear that ICT is changing the current tourism environment and it allows more flexibility and accessibility within this particular industry. Although the tourism sector is not wholly driven by ICT, it is a prominent enabling technology. The tourism industry needs to use technology to improve productivity in reaching a broad and diverse customer base. To do this, it must be flexible and responsive to rapid change as well as be stable and responsible to its existing customer base and suppliers. It will be imperative to have strong relationships with customers and to use technology for frequent, interactive communication and targeted benefits.

Bloch, M et al identified three critical factors which need to be taken into consideration when designing an ITC enabled tourism landscape namely:

- Integration: each of the systems should be as integrated as possible and should represent a "one-stop" shopping experience. This will require standardisation among the different suppliers, in terms of data, functions and organisational procedures.

- Customisation: take advantage of technology to map as closely as possible the interests of the customer. As such, it should track each customer's profile, and present only the most relevant information. Each customer's interaction with the system should be used to increase the relevance of the relation

- Pro-activity: instead of simply waiting for customers to "drop-in", all of the ICT systems should strive to create travel needs. For example customers should be tempted to by a leisure travel package by presenting information on attractive areas and sites or by making available information relevant to professionals, they would be attracted by conferences in similar fields.

4.8 International Government Support

This section of the report deals with a comparison done in terms of what other countries are doing to grow their tourism sector by means of utilisation of various government support programmes and mechanisms. It also provides an idea of how important the tourism sector is within other economies and what the lessons are to be learnt from these emerging tourism destination countries.

The countries that an analysis has been done are Australia and Ireland.

Ireland was chosen as a case study for the tourism industry because of its good tourism strategy in terms of meeting their objectives. Lessons could be learnt from making use of the tourism sector to develop the SMME market. The tourism board is also very active. Interestingly to note, Ireland is known as the silicone valley of Europe with the biggest IT industry away from America. Ireland is the second largest exporter of software in the world, second only to the United States. This could be interesting to look at how Ireland although it is a small state have developed their specific sectors

Australia was the second appropriate benchmark. Its tourism board is quite well developed and it has a cultural heritage as well as challenges similar to that of South Africa. The Australians have a wide variety of cultures within one country. Aboriginal arts and crafts are well integrated as an aspect of cultural tourism. Australia's location in the Southern Hemisphere creates climatic challenges similar to South Africa, specifically referring to seasonalities and climatic changes, rainfall patterns and environment. Although Australia is a long haul destination it has secured a competitive advantage form collaboration with airlines like Emirates offering cheaper flights via destination hubs like Dubai or Singapore, allowing "two for the price of one" tourist experiences.

4.9 Sector Objectives per Country

Comparison was made of the main sector objectives per country in terms of quality of the tourism, product development, human resource development and marketing of the country as an eligible tourism destination. Secondary objectives are also worth mentioning like creating employment, developing business environment and research, but for the purpose of the study focus has been made on the common four objectives that are transparent within Ireland, Australia as well as South Africa.

Quality relates to aspects like grading systems and hotels to ensure that the guests are satisfied with their experience. Product development relates to constantly enhancing various product offerings and services that tourists have access to and includes aspects like hospitality, tour operations, transportation, leisure and entertainment.

Tourism marketing encompasses an analysis of tourism markets, marketing objectives, and strategy as well as promotional techniques in order to reach the domestic and international tourism market. Human resource development involves enabling the collective capabilities of people involved in the various tourism elements and leadership, management and technical skills.

Table 11: Comparison of sector objectives per country

Main Sector Objectives	**Countries**		
	Ireland	**Australia**	**South Africa**
Quality	X	X	X
Product development	X	X	X
Marketing	X	X	X
Human Resource Development	X	X	X
Creating employment	X	X	X
Business environment and development	X	X	
Information, Intelligence and Research	X		

4.10 Sector Requirements per Objective

The preceding tables provides a comparison between Ireland and Australia in what they are trying to do and what the countries require in order to meet their specific objectives of growing the sector as well as ensuring that the sector is sustainable and illustrates the requirements of what Ireland and Australia are doing in meeting their sector objectives within the travel and tourism industry.

4.10.1 Quality

The table below presents a summary of types of requirements activities that Australia and Ireland are doing terms of meeting the sector objective of quality.

Table 12: Quality

	Ireland	Australia
Quality	Pro-competition regulation Utilising government instruments of economic policy Taxation Charges for services Keep inflation under control and below Eurozone average Quality of product and service	Reputation for quality, value and variety Utilise the Accreditation system • Improve industry standards • Provide information to consumers • Frequent auditing

	Up to date market research	• Platinum Plus destination Exceptional experience with superior standards Better information for investment decisions, niche markets, understand consumer needs Risk Management High raised standards

As can be seen from the grid above it is quite clear that both countries are focusing on gaining a competitive advantage within their sector by providing quality products as well as services. Ireland does this by utilising government instruments like taxation and inflation as well as focusing on market research. Australia has a programme known as the accreditation system which enables a voluntary improvement to the industry through SMME markets and it also has a frequent audit. This information is then transferred to the customer.

4.10.2 Product development

The table below presents a summary of types of requirements activities that Australia and Ireland are doing in terms of meeting the sector objective of product development.

Table 13: Product development

Ireland	Australia
Accommodation and leisure • Improvement of quantity and quality • Upgrade of tourist accommodation and associated leisure activities • Creating accommodation that is suitable for guests with mobility impairment • Develop specialist activities like golf, angling, equestrian, walking. **Sustainable tourism** • Creating Sustainable tourism • Protecting natural resources • Ensuring environmental conservation • Enhance national and local public cultural and heritage infrastructure **Business tourism** • Modernisation of tourist office network	**Accommodation and leisure** • Enabling larger companies like airlines, hotels, travel agencies to operate within the sector • Improvements in infrastructure and standards • Ongoing improvements of accommodation and leisure activities **Sustainable tourism** • Protection of sustainable tourism areas • Protection of biodiversity **Business tourism** • Building of a sustainable Business Tourism sector • Appropriate business infrastructure **Domestic Tourism** • Increase by improvements of Domestic

• Business Tourism (building a National Conference Centre) **Transportation** • Development in access transport technology • Organisations ability to be able to provide good quality services to tourists • Government investment in road and rail infrastructure • Good internal transport services	flights and transportation **Indigenous Tourism** • Cultural diversity • Accommodate tourists looking for experience and authenticity **Transportation** • Investments in roads and infrastructure • Improvement in distribution by enhancing safety and security for tourists (safety and security equipment) • Create an effective national signage system for tourists to be able to freely navigate through various areas of the country **ICT** Australian Electronic Travel Authority • Invisible visa Use information and online technologies to attract customers and do business effectively Tourism Satellite Accounts to measure effect of the tourism sector on various economic issues

From the table above it is quite clear that both countries are focusing on similar requirements and needs within the tourism sector. Both Australia as well as Ireland has a strong focus on accommodation, transportation and sustainability of the sector. Business tourism is also of high importance, there are conference centres and business centre infrastructures set up to increase the likelihood of conducting business within the countries. Australia does also have an additional focus in terms of indigenous tourism trying to accommodate the authenticity and experience of the Aboriginal cultural heritage.

4.10.3 Human Resource Development

The table below presents a summary of types of requirements activities that Australia and Ireland are doing in terms of meeting the sector objective of product development

Table 14: Human Resource Development

Ireland	Australia
Greater level of industry investment Upgrade the skill levels to highest international standards Friendliness and hospitality Training at both operative and management levels Generic training Skills based training On the job training Interventions ranging from quality assurance to programme delivery Enhancement of the level of professionalism within the industry Culturally diverse workforce – implications for training and maintaining of traditional Ireland	Highly skilled work force Friendly, efficient professional service important Sustainable high levels of service University and vocational education and training Meet new language needs and different cultures In-house training

Both countries put a considerable emphasis on training and developing human resources and skills within the travel and tourism sector. There are various interventions that they use from assuring quality to delivering a sustainable high level of service. It is interesting to note that both countries have a culture of On-the-Job Training as well as meeting language needs to provide a culturally diverse workforce.

4.10.4 Marketing

The table below presents a summary of types of requirements activities that Australia and Ireland are doing in terms of meeting the sector objective of marketing themselves internationally as well as to the domestic tourism market.

Table 15: Marketing

Ireland	Australia
Improve efficiency and effectiveness of spend in marketing and promotion by State Strong consumer research and analysis Funding directed towards advertising and media Trade promotions Production of promotional material Product innovation, packaging and presentation of tourism product	Competitive in tourism marketing and promotions Investment in international marketing Monitoring and tracking of success rate Research Film and television as active medium to provide Insight into Australia

Government funding Quantitative research Assessment of marketing effectiveness	

Marketing is a key element for any tourism sector, because this public awareness about the sector and all of the various components the country has to offer. Research and funding into the potential and untapped markets are important for both countries. A large sum of money is also invested into promotional material and advertising, trade promotions, as well as advertising that is conducted while making use of online marketing tactics. This is quite significant because it confirms the impact that the internet has and will have in the future of the tourism sector on a global basis.

4.11 Support for Sector Development

In the above section an analysis and comparison was done of the specific requirements that Ireland and Australia are focusing on in order to ensure the sustainablilty and growth of their tourism sector. In this section a summary has been made of all the types of government support programmes and inititatives that they are doing in order to ensure the requirements are met and to ensure that the tourism sector grows.

Incentives

Before going into a detailed scan of what the two countries Ireland and Australia are doing in terms of providing incentives and support to the tourism sector it is necessary to provide a brief overview of the types of schemes and incentives that are made available within the South African tourism sector context. The most common ones can be summarised as follows:

Incentive Benefits

- Critical Infrastructure Fund - which funds up to 30 – 50% of the cost of a common infrastructure
- Industrial Development Corporation Finances tourist projects through equity or loans
- International Tourism Marketing Aid Scheme Grants funding for a portion of promoting tourism projects
- Poverty Relief Fund Funds part of the cost of tourism infrastructure, new tourism products and training
- Tourism Enterprise Programme (funded by business) Provides funding for technical assistance to SMEs that supply tourist projects

In addition to these there are several generic incentives available to any investment project:

- Strategic Industrial Project 50-100% tax allowance Manufacturing and selected services, minimum investment of R50 million
- Small and Medium Enterprise Programme Cash grant of up to 10% of qualifying assets Investments R100m; benefit decreases with size of investment
- Skill Support Programme 50% of training costs, subject to a maximum of 30% of wage bill The training programme must be certifiable
- Support Programme for Industrial Innovation 50% of the direct costs incurred in development The criteria of receiving this type of incentive is that the development must be a significant technological advance and have commercial advantage over existing products
- Tourism SA is mainly funded by the government, Tourism Business Council of South Africa and the Business trust:
- Tourist infrastructure Investment Framework
- Objectives of National Tourism Spatial Framework
- National Star Grading system
- Improves quality of services
- Allows customer to choose type of experience in terms of accomodation
- Sector Skills Plan
- Education, training and quality assurance
- Ensure training of high standard
- South African Tourism Institute (SATI)
  - Teacher development programmes
  - School tourism and travel partnership
- Tourism Resource Centre
  - Bursary Scheme
  - Career promotion
  - Training of assessors and provincial tourism officials

Source: www.dti.gov.za

4.11.1 Ireland.

Ireland's tourism sector contributes 4.4% of GNP generating an annual tourism receipt of €4 billion from overseas visitors and €1 billion from domestic earnings. The 2002 receipts of tourism are equivalent to 50% of the total value of exports by Irish-owned manufacturing industry and more than twice the value of exports of Irish-owned internationally-traded services. The tourism sector's diverse small and medium sized enterprises, predominantly Irish owned, creates 1 out of every 12 jobs in the economy (equivalent to 140 000 jobs). Employment in this sector grew by more than 70% between the years 1990 and 2002, a growth rate of about 50% within that period.

Ireland's success relates to the public and private sectors that play a joint as well as complementary role in the development of tourism in Ireland. A great deal of investment is also being put in, where figures amounting to 4.3 billion pound have been projected in the last couple of years for this investment.

Current focus of sector within the country

The following section will illustrate all of the various policies and programmes that Ireland has put into place in terms of sector development in general the programmes that deal specifically with technology, although the programmes for technology concentrate specifically on ICT as this is the most influential technology within the tourism industry and can change the tourism environment as we know it.

The Irish Tourism policy is focused on sustaining growth in visitor expenditure with emphasis on regional and seasonal spread of tourism.

Key policy and programme measures

Product development in Ireland is generally funded by the European Union and consists of regional operational programmes as well as fiscal incentives for investment.

Overseas marketing receives funding from Exchequer and a large portion of the programmes concentrate on Human resource development because this is ultimately where the customer will receive his/her experience.

National Development Plan (Tourism Provisions)

This plan has an objective to support tourism clusters and develop those areas of the country that are under developed in terms of tourism traffic. They deal with facilities to ensure that disabled visitors are catered for as well as tourism environmental management.

Bórd Fáilte

This is a marketing board that deals specifically with the marketing of the Irish product abroad

MERTA

MERTA specifically deals with Rural Tourism Development and they have flagship and regional projects including major attractions and clusters of attractions as well as marketing of the domestic tourism market utilizing tourism centers as especially domestic

Programme for National Recovery

This programme is created to encourage investment in tourism by utilising schemes like a business expansion scheme (BES). They are also forming initiatives to open a feasible airline industry; competition within the airline industry has far reaching beneficial consequences for airfares and the tourism numbers afterwards

Operational Programme for Tourism

The Operational Programme has an objective to extend the tourism season and secure anchor projects that are on a large scale. They also develop cultural as well as heritage projects. Another objective in terms of Human Resource Development is to build marketing skills within the tourism enterprises and improve the training as well as human resource development of the Irish Tourism industry.

The EU grant support, resulted in some €980 million invested in tourism over the period of the Programme which is equivalent to more than the total investment over the previous 20 years.

The Tourism Task Force

They have come up with a number of recommendations to support the development of the tourism sector and ensure that there is greater co-operation between the industry as well as Government. Special initiatives have also been identified to address seasonality as well as product development within Ireland

National Development Plan

This programme has the specific objectives to identify growth targets for the industry, by this their competitiveness has improved as a result of economic buoyancy, falling inflation, Favourable currency developments, the further liberalization of air service regulations and also improvement in the political situation of Northern Ireland. The National Development Plan shifted its tourism policy objective from job creation to sustained foreign revenue earnings which made a large impact on growing the tourism sector.

Overseas Tourism Marketing Initiative

This consists of an all-island destination marketing campaign and it is structured on a public/private sector partnership. Funding mainly occurs from the Operational Programme for Tourism

The Tourism Product Development Scheme

The tourism Product Development Scheme has an emphasis on regional spread as well as cluster development; a large portion of the scheme goes towards developing niche market products and ensuring environmental sustainability.

Ireland also has a range of State fiscal, financial and advisory supports that are exchequer and EU funded. They fall under the direction of the Department of Arts, Sport and Tourism.

Multi Annual Tourism Marketing Fund

They finance all island destination marketing and niche product marketing. The main objectives are directed towards advertising, media, trade promotions as well as production of promotional material.

SUPPORT FOR TECHNOLOGIES

Information and Communication Development Programme

The objective with this programme is to maximize the use of information and communication technologies for training, marketing and customer relations management. Demonstration campaigns and co-operative networks, shared databases, web-based training, the alignment of websites for the tourism industry and as a means of communicating. The responsible body for this programme is Tourism Island.

Support Programme

This support programme deals with assisting the industry in introducing e-commerce applications. They do this by means of building capability to use e-commerce in terms of demonstrations and training. The responsible body for this particular programme is Failte Ireland.

Co-operative networks

The networks promote best practices in applying ICT and provide E-commerce strategies. The responsible body is Tourism Industry representative bodies

Training courses – New Technologies

The Responsible body is Failte Ireland and they are providing training courses for new technologies within the tourism industry. There is a computer use and operation module and the main objective that graduates from operated courses can use and apply new technologies within the industry.

Award and Recognition Schemes

The schemes promote and communicate awards to acknowledge excellence in applying ICT. The various sub-segments of tourism are focused on like accommodation, visitor centres, providing services etc. The responsible body for this is Failte Ireland.

4.11.2 Australia

The tourism sector contributes a 4.5% to Australia's GDP and the tourism input into the economy is greater than agriculture, forestry and fishing as well as communication services or gas, electricity and water supply.

Tourism generated over $17 Billion in export earnings through direct sale of goods and services to international visitors, equivalent to 11.2% of Australia's total export revenue. The tourism sector directly employ s 550 000 people and indirectly employs 397 000 people. (Australia's strategy, 2003:)

The majority of jobs in the tourism industry relate to retail trade and the accommodation sector. The infrastructure is built through investment and it contributes to cultural exchanges and fosters cultural understanding.

Current focus of sector within the country

The following section will illustrate all of the various policies and programmes that Australia has put into place in terms of sector development

Tourism Australia

This organisation is involved in marketing Brand Australia to the key global markets. Their goals are to attract major events to Australia and assist in the growth of business tourism. There is a range of research and analysis that is customised for government and market needs. Strategies are also developed on how to promote growth within the domestic tourism market as well as encourage dispersal of international tourists.

Department of Industry, Tourism and Resources

This is part of the tourism policy advice to government that tries to enhance bilateral tourism relations with other countries. They have managed to receive approved Destination Status arrangements with China. They also deal with issues like Visa and passenger processing, transport and security, education and training and regulation of industry standards. A major objective of this department is also to develop regional and niche tourism and provide regional development and business assistance programmes in order to enhance the creation of SME markets and initiatives.

Australian Tourist Commission

The Australian Tourism commission provides funding around $92 million per annum over past 5 years. In the year 2002/2003 Australian Government gave $100 million to ATC and $48 million for other direct tourism related expenses especially associated with the marketing of Brand Australia which is the campaign used to market Australia on a global as well as domestic arena.

Australian Government Agencies

The government agencies consist of various Departments and the departments that mainly deal with and support the tourism sector are the departments of Foreign Affairs and Trade that provide Australia with the public diplomacy programme as well as promotion of positive perceptions of Australia on an international level.

Austrade SMME development

The Austrade assists businesses one on one to develop international markets. It provides assistance to exporters of tourism expertise; it also provides customised market services to tourism exporters. There is a memorandum of understanding between Australian Tourism Commission and Austrade to be able to raise public awareness of Australian tourism exports. Key information resources and collaborative activities are also shared within the key markets.

World Tourism Organisation

A key contributor to global trade and economic development, thereby allowing the exchange of important information and data and provides a forum to exchange practical knowledge and experience

Bilateral Collaboration

Australia has many key collaborations with other countries and organisations particularly a joint marketing and collaboration with New Zealand as well as a Singapore-Australia Joint Ministerial Committee which allows the possibility of boosting tourism between countries, increasing international arrivals and increasing the tourism from markets like India and other Asian countries.

International Tourism Ambassadors

Australia came up with an International Tourism Ambassador Programme whereby the main objective is to provide marketing and advertising via word of mouth promotion and encourages every Australian travelling overseas and everybody visiting to take on a role as ambassador. It is an extension of Meet and Greet Programme (Sydney Olympics 2000)

Cooperative Research Centre for Sustainable Tourism

A lot of research is going into Australian and this body is the best funded national research body in world. It works with industry and governments to produce research and analysis for sustainable development in tourism and maximise support for White paper initiatives, funding is also provided to establish reputation overseas for research education and training.

Tourism Research Australia

This is a combination of Bureau of Tourism Research and Tourism Forecasting Council. The organisation is commercially focused. Tourism Research Australia addresses key information requirements and improvements on data collection, Develop yield maximisation strategies, Improve tourism forecasting, Communicate and transfer information to industry and educate investors on the tourism industry.

National Accreditation Working Group

The way that Australia tries to implement quality is by providing a voluntary accreditation system. Therefore this group is seeding the funding for an accreditation framework; they also help address the constraints to tourism accreditation as well as speed up the voluntary accreditation system nationally.

The process is nationally sped up by:

- Providing sustainability after two years without help from Australian Government
- Provides coordination and consistency in approach and branding
- Delivers value to tourism businesses by providing help in accredited business that lack back office processes
- Develops and markets a strong brand

Information and Technology Online Programme

This is the one programme that supports optimal uptake of information and online technology and they do this by means of helping smaller tourism businesses to use technology and be better connected to other businesses in supply chain. They also encourage industry to adopt e-commerce solutions that increase competitiveness.

National Centre for Language Training

This centre teaches intensive language skills and business culture of various countries. This enables a reduction in time to reduce time needed to get language and business competence.

Ministerial Council on Education, Employment, Training and Youth Affairs

The councils provide assistance in terms of:

- Agencies
- Providing courses and skill development
- Apprentice Schemes
- Technical and Further Education (TAFE)
- University Courses

Tourism Training Australia

This is a National training and advisory board for the tourism and hospitality industry. They deliver training on defined competencies within the tourism sub sectors and it is funded by Government, State and Territory training bodies and private sector

Workplace Relations Act

This is an important policy that has been set up by government and is a Collective agreement between employers and registered unions or a direct agreement between employers and employees for Australian Workplace Agreements. The Office of employment Advocate has network of industry partners and ambassadors and promotes and assist in developing AWA's as well as providing an Action Agenda Process in taking up of AWA's with restaurants and the catering industries.

Australian Tourism Development Programme

This programme provides research around tourism development planning and support to develop Platinum plus products and experiences, it also allows the filling of gaps within existing products/services as well as contributes to long term employment and collaboration between tourism organisations and operators.

Indigenous Tourism Business Ready Programme

This programme provides the assistance in commercialisation of indigenous services and products. The government provides intensive support for two years and Develops business management capacity. The graduate at the end of this business ready programme will be mentored into venture capital markets as well as alliances with industry. Support to work of indigenous Tourism Leadership Group.

National Tourism Signing Reference Group

An important requirement within product development is providing the development of more effective national signage system. This reinforces the marketing and help with efficient travel therefore the National Tourism Signing Reference Group has been established with the objectives that this occurs

Tourist Refund Scheme

This refund scheme is beneficial for the tourist and allows international tourists to claim back GST and WET (wine equalization tax). The objectives by doing this is to Increase Duty free allowance to encourage travel as well as benefit from faster processing times and increased tax concessions

To develop infrastructure

- Development of National Cooperative approach to coastal issues
- Reef Water Quality Protection Programme
- Representative Areas Programme try to protect reef environment, protection of the biodiversity and provide funding and investment in these parks.

Domestic aviation policy

The policy allows the market to operate freely and increased access by international carriers and new entrants into the domestic market. It is a highly liberal Australian policy and subsidies for control tower services as well as lifting air services charges on smaller aircraft operations.

Auslink

Is a scheme improves freight logistics and increases rail competitiveness along major transport corridors, it also tries to reduce the amount of freight on the roads which is great benefit for tourism.

National Cruise Shipping Industry Strategy

This strategy facilitates Australian owned and operated ships and deals with regulatory and taxation issues.

Other programmes:

Although Australia cannot be regarded as a developing country, it has undertaken some very innovative approaches to developing its cultural tourism industry regarding the Aboriginal people:

“Stories of the Dreaming” is collaboration between Australia's Cultural Network (through the Federal Department of Communications, Information Technology and the Arts) and the Australian Museum. The stories come from the cultures of Indigenous Australians and have been collected from all over

Australia. They reflect an essential part of the life of Indigenous Australians. These are available through their Website1

The following table provides a brief summary of what Australia spends on supporting the various organisations and activities within the tourism industry.

Table 16: Summary of Australian spending

Activity	**Agency**	**Spending ($ Million)**
Australian Tourist Commission	Industry, Tourism and resources	100
Export Market Development Grants	Austrade	17
Regional tourism projects	Industry, Tourism and resources	9
See Australia	Industry, Tourism and resources	2
Bureau of tourism research	Industry, Tourism and resources	2
Cooperative Research Centre for Sustainable Tourism	Education, Science and training	3
Australian Bureau of Statistics	Australian Bureau of statistics	2
Conservation of Rural and Historic Hotels	Environment and heritage	4
Tourism policy	Industry, Tourism and resources	9
Total		148
Source: Australian White paper Strategy pg 16		

Source: Adopted from *Australian White Paper*

CHEMICALS SECTOR

5 TECHNOLOGY DEVELOPMENT TRENDS OF THE CHEMICALS SECTOR

5.1 Global Overview of the Chemicals Industry

Broadly, the market of chemicals can be classified into petrochemicals products, organic products, inorganic products, polymerisation products, basic chemicals, fine chemicals and pharmaceuticals.

The sector is predominantly mature and highly competitive with low margins. 70% of global chemical production, and 65% of global chemical consumption, are located in Japan, the USA and the EU.

The chemical industry is also its own biggest customer with about 60% of production used in downstream manufacturing within the sector.

In the commodity sector, market share is the determining measure and driver for performance. Currently there is significant overcapacity in the sector affecting ethylene, benzene, styrene, alpha-olefins and phenol.

Globalisation and international trade are here to stay, but access to certain markets will be hindered by regulatory compliance issues. In particular, concern for and practices affecting the environment are becoming significant conditions for market access coupled with a greater understanding and requirement of Life Cycle Analysis (LCA) resulting in cleaner production as well as the use of renewable resources.

Regulatory trends that favour one product or technology over another (such as emissions and thickness of plastic bags) are generally getting stricter and compliance is necessary to stay in the game.

5.2 Global Trends

Feedstock Trends:

To a large extent, the chemical sector's feedstocks are inorganic substances, crude oil and gas, all of which are non-renewable resources.

There is trend towards the use of natural products and the use of waste streams and multiple feedstock options through multi-step synthesis reactions.

There is a significant trend towards gas-to-liquid technology for fuel and feedstock production.

Manufacturing Technology and Innovation:

Green chemistry is a significant driver of change. In the future it will be crucial to bring biotechnological expertise, along with materials and engineering knowledge, to chemistry to develop new renewable raw materials, alternative catalytic solutions, and more benign solvents and chemicals.

Product substitution trends will result from newer technologies and products.

Process improvement will be essential in order to meet increasing environmental, efficiency and quality standards - the industry is generally under pressure to improve its environmental record and its sustainability.

Catalysts will play an even greater role with 60% of chemical production and 90% of chemical processes already dependent on catalysis.

5.3 Research and Development Trends

Spending levels, as a percentage of turnover, are not expected to change (in the US this varies from 2% in basic chemicals, 4% in polymers and up to 10% in pharmaceuticals.

In Germany, the R&D spend has moved from 5,8% in 1995 to 7,3% in 2000).

Companies in the life sciences will continue to be major drivers of product innovation due to higher R&D expenditure and advances in bioinformatics, genomics and proteomics.

5.4 Technology Development Trends

This heterogeneous sector is expecting somewhat different development paths depending on the sub sector. While specialty chemicals most likely will be significantly influenced by nanoscience and biotechnology in the future, the changes envisaged for basic chemicals (i.e. petrochemicals, bulk polymers and fertilisers) are thought to be more based on **evolutionary development**. **Disruptive innovations are difficult in basic chemicals industry since they have to fit with existing infrastructure of both the industry and society.** Fuels and fuel distribution infrastructures, for example, are very rigid systems and cannot be easily changed. For breakthrough technologies to appear, great external pressure would have to be applied to the system, like severely increased oil prices for a long time or a powerful political agenda with a strong desire to change policy in a concerted way over a big field. Such a scenario could allow for green chemistry, based on biochemistry, which would compete on more equal footing with, or even partly substitute, the traditional oil based chemical processes. However, this is not considered likely to happen by the interviewed experts in the basic chemicals sector on a 15 to 20 years' time horizon and the industry seems rather to be prepared for a more evolutionary pathway. In this evolutionary development, every traditional category of materials will be important since the trend is the growing of cross-linkages between them. The clear trend globally of convergence of different strands of science and technology and knowledge transfer between different materials and scientific fields will grow even stronger. In the following sections, issues and developments of concern for both basic and specialty chemicals will be presented even though many of them most likely will have an impact on the latter in a shorter time frame. However, eventually, as cost goes down and accessibility increases of emerging synthesising paths, catalysts, biochemical processes, prediction of material structure and properties, reaction and separation systems, measuring equipment and simulation tools, the manufacturing of basic chemicals will be influenced as well.

5.5 New Production Processes

5.5.1 Improving chemical processing

Current chemical processes, their design and usage often rely on empirical, semiquantitative techniques. Integration of basic engineering sciences like thermodynamics, kinetics and transport phenomena offers a huge potential for a better understanding of the processes, which in turn could permit higher capital utilisation, improved yield, less waste etc. Advances in measurement techniques and computational technology together with improved systems integration could then enable process synthesis, which would permit early assessment and evaluation of the possibility of manufacturing products resulting from new chemistries. In this context, integration of process control and optimisation on both plant level and multisite level will be highly relevant and could provide positive effects like cost savings, better utilisation of material and energy, less waste and minimisation of environmental impact. At the same time, the flexibility of the various processes needs to be improved so that they can be easily adapted to customers' need. During all stages, developments of disassembly procedures for recovery or reuse of materials must be kept in mind.

New processing concepts are expected to emerge like bioprocessing, new reactor and separation technologies and recycling. There will be an integration of reaction and separation stages like, for example, in reactive distillation. New separation techniques, based on membrane technology, to be used for hydrogen separation for example, are heavily supported by fuel providers and is supposed to emerge within the discussed time frame. Microreactors will most likely also be developed. This technology is generally expected to have advances in better yield, inherent process safety and intensive materials and energy exchange.

5.5.2 Controlling the process

To reach these improvements in process technology, advances in measurement techniques and computational technologies will be decisive. Traditional quality control laboratories could then be replaced by real-time, continuous, in-process measurement systems, which would give immediate feedback to the process and, thus, enhance quality as well as usage of raw material and energy and, thus, have an overall positive impact on cost as well as on environment. In this context, sensors are expected to play an important role. Sensors could also be used at the end of a process to control emissions. Furthermore, new sensors could allow the development of new cleaning systems for piping in chemical plants which would be more environmentally friendly than today's options. It is considered that nanotechnology will be the fundamental enabling technology for creating new sensor products, which to a large extent will be found in chemical manufacturing.

5.5.3 New processes

In terms of desktop manufacturing processes, some interviewees see e-business coordinating the supply of information or specifics, tailored to them, as a new dimension in chemical activities. The outcome is business tailoring itself to specific customer requirements, especially with very close customers. This is because within the chemical industry, a few key customers provide a significant part of turnover. Intensive new processes are developed everyday. All these activities aim at reducing costs and lowering waste. A good example is coal tar being used for producing benzene, but it is more costly than the current resource (oil). This appears to be a common pattern in the chemical sector: one finds an alternative to the current production process, but it is more expensive.

Intelligent processing is a part of the industry's on-going continuous improvement: it is very relevant and will continue to be for future competitiveness. Recycling activities are relevant, as industry and customers look at the product's entire life-cycle.

5.5.4 Measurement and computational technologies

Both chemical science and chemical processing need to be supported by highly sophisticated measurements and data processing technologies and simulation programmes.

Measuring and simulating on laboratory and production scale

It is just as important to continue to develop highly sensitive and precise measurement technologies to be used in the laboratories to probe molecular processes, as it is to make sophisticated measurement tools and equipment more robust and user friendly so that they can be used not only in research laboratories but provide real time, on-line data in the factory.

In the same way, modelling has a broad range of applications from the molecular level to process simulation and control. It is now possible to accurately study systems of a few tens of atoms through computational molecular science but as more atoms are considered, the computational complexity and cost increase in an extreme way. Single phase fluid dynamics modelling tools are being extended to multiphase systems but the issue of including kinetics, heat and mass transfer dynamics and thermodynamics to computational fluid dynamics programmes has only began.

5.5.5 The use of measurement and simulation in production

At the manufacturing site, processes will be measured, simulated, automated and controlled in a much more rigorous way than today. This will support both process control as well as the environmental situation. To achieve this, capability, accuracy and speed of measurement techniques need to improve. Sample preparation may not be needed for routine measurements and the analysis cycle time could be dramatically reduced. Regarding simulation, computational fluid dynamics programmes in combination with chemistry could support experimental optimisation and the following scale up to plant size. With the adaptable manufacturing processes that are anticipated to evolve in the future, computer modelling based on precise measurements would have to provide the necessary reconfiguration data in a reliable and quick fashion. Optimisation of energy and raw materials will also be supported by real time reliable measurements and simulation for which new models, software solutions and professional competence are needed. This could lead to both economic and environmental advantages.

5.5.6 Emerging technologies

5.5.7 Materials Technology and Nanotechnology

The following table is taken from the survey carried out in this project, by the interviewing 45 experts (on a list of 300 contacted) on the subject of materials innovation. The table summarizes the results of the survey that directly or indirectly deals with the chemical sector:

Table 17: Diffusion of new material technology

TECHNOLOGY	2005	2010	2015	2020	AFTER 2020
Fibrous materials (carbon fibers, organic fibers)	GR		MA		
New concrete	GR		MA		
Polymer blends	GR		MA		
Ceramic synthesis (sintering, coating, finishing)	EM/GR	GR	MA		
Adhesives	GR	GR		MA	
Multimaterials	EM/GR	GR		MA	
High critical temperature materials	EM/GR	GR		MA	
New and improved processing techniques	EM/GR			MA	
Nanopowders	EM	EM/GR	GR	GR/MA	
Conducting polymers	EM/GR	GR	MA		
Biopolymers	EM	GR			MA
Intelligent processing	EM/GR	EM/GR			MA
Nanocomposites	EM	GR	GR		MA
Functional and smart polymers	EM	GR	GR		MA
Carbon nanotubes	EM	EM/GR	GR		MA
Aggregation techniques of nanoparticles	EM	EM/GR	GR		MA
Bio-inspired materials	EM/GR	EM/GR	EM/GR		

EM = Emergence GR = Growth M= Maturity

Source*: Adopted from CM International and Fondazione Rosselli.*

5.5.8 Materials Structure and Properties

With the expected knowledge of prediction materials properties and the precise manipulation of materials structure follows a range of opportunities. Materials with increased functionality, special characteristics and extended performance range are expected to be developed. The manipulation includes technologies like molecular self-assembly, materials catalysis and net shape synthesis, which would have to be (further) developed. The manipulation must not stop at the nanoscale, but continue to macroscale to enable the processing and manufacturing of materials with specifically tailored properties. It is expected that it will be possible to design materials with certain properties from the molecular level to the final product, relying on computational tools. These new approaches to the design and manufacturing of materials can help facilitate the incorporation of life-cycle considerations into the design phase and can support the reuse or disassembly of materials.

5.5.9 Examples of New Materials

Technological standards stimulate innovation especially regarding use of secondary raw materials. For instance, in construction activities, effervescence with new materials is a problem and most current ways of dealing with this use are environmentally unstable. Glazed ceramics require significant amounts of energy, they are expensive to extract and require a glazing material. Cements fired at a much lower temperature can have similar performance; unfortunately it is the anaesthetic target which has not quite been hit as yet. There is also a trend towards using secondary materials and by-products from other industries, to form part of a new material. For example, quarrying operations produce significant amounts of dust which other companies compress to form blocks, to be used for the construction industry, even if there is a number of technical issues still to be solved.

Applications of the ability to manipulate materials on an ever-decreasing size level are expected to be developed in both modifications of conventional materials (available at earlier stage) and completely new ones.

Hybrid materials and mixed materials are likely to be on the market by 2020. There is a high potential for nanocomposites (2010-2015) with multi-functional properties and with broad application possibilities. The timing of this technology was said to depend to a large extent on if and when bulk production in certain areas comes about and, thus, economically enables the wider use of certain composites. Low weight and high strength materials will be developed, for use, for example, in the automotive industry. Other examples of material applications considered highly interesting are nanostructured alloys, sol-gel, ultra thin coatings or layers (e.g. for high efficient photovoltaic cells), materials for the microelectronic industry etc. Nanofluids and MEMS (microelectromechanical systems) are research topics, which would benefit from public support according to the interviewed experts.

5.5.10 Technologies enabled by material developments

The ability to structure and, thus, control properties of surfaces and interfaces may have a great impact in areas like catalysis, surface treatment and coatings. Smart materials (2015-2020), with a high economic potential driven by both design (e.g changing colours) and functionality (self-repairing, materials with 'memory' etc.), is also a promising area. Enhanced performance of materials may also lead to the development of the wider use of sensors in the chemical process industry. Future sensors might utilise a range of technologies including MEMS (microelectromechanical systems), piezo-materials, micromachines and VLSI (very large scale integration). Likewise, material developments are expected to allow for improved chemical processing and separation processes by, for example, new types of membranes, which can be used at high temperatures and aggressive conditions.

5.5.11 Materials for energy systems

Energy production, storage, transportation and optimisation were stated to be key technologies and the materials to provide these were said to have a bright future potential. Consequently, this will be one of the areas where the chemical industry will devote substantial effort. Examples of such materials are nanocarbon tubes for fuel cells and hydrogen storage, polymers for fuel cell membranes and high temperature materials, which could be used in combustion engines or elsewhere in energy production. More efficient incineration processes would be made possible by developments in membranes resisting high temperatures and aggressive environments as well as by the development of separation and production of oxygen (2015-2020). Regarding energy transportation, there is room for big improvements. New materials for conductors, carbon nanotubes used like supra conductors at room temperature would change this area completely, as would magnetism to control electric fields. This could be paralleled with restructuring today's energy production and distribution systems, by introducing many small plants (particularly using renewable sources) distributed all over the EU and connected by networks.

5.5.12 Polymers

Polymers are increasing their application fields continuously and today, polymers for electronic components (thus replacing silicon) show their first promises (printed circuits). Bulk production is expected in five to ten years' time. The potential is very high as the technology could provide low cost materials for the microelectronics industry.

Moreover, recycling of microelectronics products would most likely be easier accomplished if they mostly contained polymers. The major microelectronics companies in the world are investing heavily in R&D in this area and today, the US are thought to be ahead of Europe. Polymers from renewable resources, maybe produced through genetically engineered organic sources, may be in place by 2015-2020. It would have a positive environmental impact and would assure strong competitiveness to producers. Likewise, biodegradable polymers ought to be environmentally justified. Polymers for fuel cell membranes and high temperature polymers are further examples where important developments are expected. In general, polymers will be more and more customised and this will be increasingly important to manage for the petrochemical industry, with flexible and precise production.

5.5.13 New synthesis techniques

To synthesise these new materials discussed above, new techniques have to be developed which incorporate disciplines like biology, physics and computational methods and, importantly, new catalysts. The structure and, thus, properties of the material must be controlled through the synthesis to achieve the multifunctionality required. The more targeted synthesis paths would most likely result in fewer processing steps. Examples of new syntheses sought for are the production of hydrogen and methanol. Breakthroughs in the direct production of methanol could facilitate the shift to C1-feedstock and provide cheap resources for fuel cells in the long run. Techniques for stereospecificity in chemical synthesis processes will be necessary in order to achieve the precise properties and highly special catalysts will be needed to control these synthesis paths.

5.5.14 Catalysis

Catalysts are a central part of chemical synthesis. About 90% of current chemical processes make use of catalysts and, so, it is obvious that a great deal of attention is given to this area to improve and expand synthesis paths. There is still a lack of understanding of the fundamental mechanisms taking place at the surface of a catalyst and this means that today's R&D have a very high empirical component. Nanotechnology is expected to help to improve the understanding of catalysis and by doing so, existing catalytic processes can be improved and new ones can be designed and developed as the structure and property of nanostructured catalytic materials can be controlled. A deeper understanding of surface mechanisms and the development of sophisticated measurement and simulation tools will be needed to find catalysts for special applications and to forecast their characteristics. New and improved catalysts would allow new products as well as more targeted synthesis paths with higher selectivity, resulting in higher yield and less waste. This fits well with the life cycle approach that is necessary to take into account for future chemicals production. Examples of areas of interest are new catalysts for customised polymers, catalysts for stereospecificity, catalysts with long life and self-repairing abilities, catalysts to convert product molecules and polymers back to useful starting materials, catalysts to be used in catalytic distillation, catalysts for methane and other C1-feedstock and enzymatic and biocatalysts. A dream reaction is the direct oxidation of methanol from methane.

5.5.15 Biotechnology

Biotechnology and bioprocesses are treated as a separate issue below. In fact, the technologies under these headings could very well have been spread out to the sections on materials, syntheses, production processes etc. but are chosen to be presented together for reasons of clarity. Biochemistry in general is expected to face less problems with public acceptance in comparison to the field of agriculture. It is clear that specialty chemicals, with lower volumes of production, are likely to see the most profound impact of biotechnology and that the production of basic chemicals will change much less over the next 10 to 15 years. However, there are still developments for the latter to take into account even in the most conservative scenarios. Several experts estimate that by 2020 and beyond, green chemistry will have reached bulk chemical production in a serious way. In some areas there will be concurrency between biotechnology and traditional chemistry approaches and markets will decide in each case. The area of possible research is enormous and setting priorities is thought to be critical. The use of biocatalysts has already been mentioned and is one of the areas that might be chosen for substantial research efforts. Another such area is improved biochemical processing. Developments in these areas could be used to find short and direct ways to synthesise organic materials under normal conditions (temperature and pressure). Low cost materials for bioprocesses may be derived from forestry and agricultural wastes and, also, to an increasing extent, cultivated feedstock crops. There could be a real boom for biofeedstock if and when fuel cells enter the market since hydrogen could be produced from biogenic methanol. A technical problem that has to be overcome in this context is the varying quality of biogenic feedstock. Biopolymers (compatible with organic material) are an often mentioned topic but which will mostly be aimed at more specialised applications in health care. Finally, bioelectronics with its potentially high capacity of handling information is another exiting area but which is more speculative.

Table 18: Emerging technologies in the Chemicals industry

	PRODUCTIVITY	DEMAND	YEAR OF DIFFUSION
Mass-synthesizing technology for fullerene carbon compounds.		M	2010
Photo-catalysts for organic synthetic processes.		M	2010
Artificial high performance catalysis for manufacture of chemicals near normal temperatures and pressures.	H		2010
Organic ferro-magnetic materials.		H	2010
Bio-plastics, Polymer conductors.		M	2010
Self-healing high polymers.		M	2005
Selective catalytic cracking technology for naphtha.	H		2008
Direct synthesis of phenol from benzene.		M	2006
Combinatorial chemistry.		M/H	2006
Chiral chemistry and asymmetric catalysis.		M/H	2004
Advanced enzyme evolution techniques.		M	2004
RNA catalysis.		H	2010
Biomimetic catalysis.		H	2010
Advanced zeolite catalysis.		H	2003
Polymer functionalization.		H	2003

The following section provides a deeper explanation of some of the technologies that will have a significant impact on the industry, globally.

5.6 Technology Description

5.6.1 Biosciences (Bioprocesses and Biotechnology)

Biotechnology is a key technology for many chemical companies seeking to remain competitive in today's global market and to meet the demands of increasingly stringent environmental regulation. Biotechnology is particularly important for companies producing high-value products such as pharmaceuticals, fine chemicals and speciality chemicals.

The chemical industry has used traditional biotechnological processes in the form of enzymes and antibodies for many years in the large-scale production of detergents, antibiotics and chemicals such as citric acid. Since 1980, there has been an explosion of scientific advances in the use of enzymes, fermentation, bioremediation, protein purification and genetic modification via recombinant DNA technology. These developments have revolutionised biotechnology's potential. Drawbacks such as low yield, slow throughput and low stability have been largely overcome.

Biotechnology Applications in the Chemical Industry

A large number of well-established biological processes are now used in chemical manufacture. Some companies are realising the benefits that biological catalysis (biocatalysis) can provide for large-scale and smaller-scale production, particularly in the fine chemicals sector. These benefits include:

- biotransformations enabling the production of high-value products (eg pharmaceuticals and other bioactive chemicals such as herbicides)
- cleaner and more sustainable processes
- the use of renewable feedstocks for bulk chemical production.

Chemical companies are also using biotechnology to treat solid, liquid and gaseous waste streams and to clean up contaminated land to meet regulatory consents and authorisations.

The application of biotechnology in the chemical industry is summarised in the following table.

Table 19: Applications of Biotechnology in the Chemicals Industry

Application	Petrochemicals	Plastics and polymers	Paints and pigments	Agrochemicals	Specialities	Pharmaceuticals	Nutraceuticals	Cosmetics	Soaps and detergents
Feedstock		x					x		
In-process									
Biocatalysis		x		x	x	x	x		x
Fermentation				x		x	x		
Monitoring									
Product quality					x	x	x	x	
Authenticity tracking	x	x	x	x	x	x	x	x	x
Direct toxicity assessment		x		x	x				
Waste management									
VOCs and odours		x	x	x	x		x		x
Wastewater	x	x		x	x	x	x	x	x
Solid waste	x			x	x		x		x
Land remediation	x		x	x	x	x	x		x

Biocatalysis: Applications and Benefits

One of the first examples of biocatalysis in the pharmaceutical sector was the production of semi-synthetic penicillins. Biotechnology is now widely used to manufacture a growing range of products (eg 6-aminopenicillanic acid (6-APA), aspartame, l-methionine, vitamin B12 and vitamin C). Biocatalysis, in combination with conventional organic chemical synthesis and purification, allows pharmaceutical companies to significantly reduce the number of synthetic steps and increase production efficiency, particularly for drugs based on chiral compounds. These are compounds which occur as pairs, each composed of the same atoms but structurally arranged as mirror images of each other. Compound pairs are known as enantiomers and although they have identical compositions, they have specific and quite different biological effects. One enantiomer may actually produce unwanted and possibly harmful side effects. Therefore, isolation and purification are essential. Thalidomide is a well-known example: one enantiomer had the desired pharmacological effect of preventing morning sickness during pregnancy, while the other caused deformities in the developing foetus. The increased demand for drugs based on chiral compounds has created a major market opportunity by stimulating demand for chiral intermediates. Biocatalysis is now widely used for producing drug candidates based on chiral compounds. The highly selective nature of enzymes can also be applied in the manufacture of agrochemicals and even in the production of some commodity chemicals, notably acrylamide.

The technology for developing new biocatalysts is well-advanced and can be adapted for product-specific reactions. The technology does not necessarily require modified equipment and, provided they are handled carefully, biocatalysts can be used by nonspecialists.

In-process monitoring using biosensors

Biosensors combine biological selective reactivity with the processing power of modern electronics to provide powerful analytical tools that are able to rapidly detect tiny amounts of particular substances. The biological component (eg an enzyme or an antibody) reacts with the substance of interest to produce a physical or biochemical change (eg giving out light or changing colour) that is detected and converted to an electrical signal by the electronic component (eg a transducer). Applications for biosensors in the chemical industry include monitoring and control of production processes, particularly where microbial contamination can occur. Early detection of micro-organisms can limit the risk of product deterioration and the level of biocide dosage which may be required for clean process water. Antibody test kits can be used to detect the presence of potentially hazardous substances.

New methods of producing recombinant monoclonal antibodies offer a rapid way of manufacturing 'bespoke' antibodies for detecting the presence of a wide variety of complex molecules.

Biocoding

The property of antibodies to react with specific chemicals can be adapted for use as a product 'brocade'. A UK-based biotechnology supplier has developed a tracer system that uses this principle. The company supplies a chemical tracer that can be detected by antibodies. A simple test can easily determine the authenticity of manufactured products and remove the threat of counterfeit alternatives which might be inferior or adulterated.

Biotechnology for waste management

As well as reducing waste and improving in-process efficiency, biotechnology can provide companies with cost-effective, end-of-pipe waste treatment. It can also be used to clean up contamination and to carry out environmental monitoring.

The main uses of biotechnology for end-of-pipe treatment in the chemical industry are effluent treatment and emissions abatement. However, biotechnology can also be used to treat solid waste with a high organic content. Composting technology has advanced considerably and solid waste can now be biodegraded under highly controlled conditions that minimise odour and leachate. Modern closed systems operate continuously or in batch mode.

Effluent treatment

With legislative pressure expected to continue, on-site treatment has become an increasingly attractive option, offering the advantages of reduced discharges to sewer, significantly lower disposal costs and reduced environmental impact. Therefore, many companies have chosen to install their own effluent treatment plant or to improve an existing system as a way of saving money and complying with legislation. Better management, monitoring and control of existing systems can also enhance performance.

Emission abatement

Some chemical companies emit volatile organic compounds (VOCs) or produce odours from their manufacturing processes. There is strict legislation limiting VOC emissions in the UK because of their impact on air quality and, while odours may not be harmful, they can lead to complaints and negative publicity.

Depending on the composition and volume of a contaminated air stream, biotechnology offers lower capital and operating costs compared with alternative systems such as thermal oxidation. Methods such as bioscrubbing and biotrickling filters degrade VOCs and odorous compounds generated from process emissions.

Environmental monitoring

Biosensors can be used to measure a range of environmental parameters such as COD and toxicity. Biosensors offer a quicker and potentially cheaper alternative to conventional testing methods for toxicity assessment. Current approved tests can be time-consuming, thus making rapid assessment of toxicity difficult.

Bioremediation

Soil and groundwater contamination are an ever-present possibility for companies operating at sites with a history of industrial activity. Over the last 15 years, bioremediation has become a tried-and-tested method for treating contaminated land and groundwater. Naturally occurring micro-organisms convert pollutants in the soil or groundwater to harmless, or more environmentally acceptable, compounds. In a range of applications, bioremediation has been shown to offer significant cost and environmental benefits in comparison to alternative technologies. Commercial bioremediation technologies for the treatment of contaminated land and groundwater can be divided into ex-situ and in-situ methods. ‘Ex situ’ means excavating the soil before treatment, whereas ‘in situ’ means the soil remains in the ground throughout the treatment. There is a wide spectrum of approaches ranging from minimum intervention in-situ techniques to more expensive ex-situ reactor systems. Similarly, groundwater can also be treated in-situ or pumped to the surface for treatment in purpose built bioreactors. A key advantage of this technique is the ability to treat contaminated ground without disturbance to infrastructure or production activities.

5.6.2 Catalysis / synthesis

Chemistry in alternative reaction media (gas phase, water, supercritical fluid, etc.). New synthesis techniques incorporating the disciplines and approaches of biology, physics, and computational methods.

5.6.3 Nanotechnology

Nanotechnology is defined as the fabrication of devices with atomic or molecular scale precision. Devices with minimum feature sizes less than 100 nanometers (nm) are considered to be products of nanotechnology. A nanometer is one billionth of a meter (10-9 m) and is the unit of length that is generally most appropriate for describing the size of single molecules. The nanoscale marks the nebulous boundary between the classical and quantum mechanical worlds; thus, realization of nanotechnology promises to bring revolutionary capabilities.

Fabrication of nanomachines, nanoelectronics, nanophotonics and other nanodevices will undoubtedly solve an enormous amount of the problems faced by humankind today.

5.6.4 Process intensification

Process intensification refers to technologies and strategies that enable the physical sizes of conventional process engineering unit operations to be significantly reduced to achieve radical capital, energy, environmental and safety benefits.

A number of techniques and equipment e.g. Higee, printed circuit Heat Exchangers, high intensity mixers, intensified separation and spinning disc reactors .

5.6.5 Combinatorial Chemistry (including high throughput technologies)

Combinatorial chemistry is one of the important new methodologies developed by academics and researchers in the pharmaceutical, agrochemical, and biotechnology industries to reduce the time and costs associated with producing effective, marketable, and competitive new drugs.

Such trends include pursuing therapeutic efficacy, addressing 3-D structure within database settings, assuring absorption, directing distribution, controlling metabolism, optimizing elimination, and avoiding toxicity. As the exploration of these topics proceeds by deploying combinatorial chemistry coupled to high-throughput screening, medicinal chemistry will play a key role in interpreting the underlying structure-activity relationships. This will cause the overall process of drug discovery and development to be knowledge generating. As fundamental knowledge accumulates across all of these areas, virtual approaches will eventually become firmly anchored to experimental and theoretical databases having validated clinical predictability.

Combinatorial chemistry creates vast numbers of compounds by simultaneously reacting a set of components in thousands of different combinations. The technique is continuously altering the way scientists develop new materials and drugs.

Discovering new substances is the key to sustaining growth in high-tech products. As with conventional materials discovery programs, combinatorial chemistry is projected to bring a reasonable return on investment when its targets are high-cost, high-value, high-demand materials used in fields such as communications, electronics, photonics, advanced packaging, and self-assembled materials.

By producing larger, more diverse compound libraries, companies increase the probability that they will find novel compounds of significant therapeutic and commercial value.

While combinatorial chemistry can be explained simply, its application can take a variety of forms, each requiring a complex interplay of classical organic synthesis techniques, rational drug design strategies, robotics, and scientific information management.

The field represents a convergence of chemistry and biology, made possible by fundamental advances in miniaturization, robotics, and receptor development.

Combinatorial Chemistry Applications

Combinatorial chemistry provides a means of increasing the amount of chemical information available to materials discovery groups by a factor of 10,000. The ability to observe the properties of thousands of materials nearly simultaneously gives scientists a big-picture view on materials discovery.

In the pharmaceutical and biotechnology arena, lead compounds for the treatment of Alzheimer's disease, tuberculosis, and inflammatory disorders are being developed. Combinatorial drugs for pain, cancer, HIV, lupus, and asthma are in clinical trials.

Combinatorial chemistry has become an integral part of drug discovery, and will benefit from the growing number of validated targets resulting from genomic and proteomic research. Identifying a drug target, however, forms only one part of the drug discovery process. Subsequently, the isolated target needs to be characterised before a therapeutic can be developed. In a growing number of cases, this therapeutic is a small molecule derived from combinatorial chemistry screening.

Combinatorial Chemistry requirements

Investment in combinatorial chemistry (combichem) in the pharmaceutical industry is being driven by the need for increased efficiency. Results from pioneers in the field have demonstrated where mixture or discrete compound synthesis is useful, and what mixture sizes and compound concentrations are appropriate. To make the techniques of combichem of general utility in drug discovery, a broad range of advances is still required. Conversion of organic chemistry to solid phase conditions is key, as are developments in linkers and resins. Library design methodology requires further development. Combinatorial biosynthesis of focused libraries of natural products holds great promise for capitalising on hardwon natural product leads. Miniaturisation of screens is required to reduce the cost of screening combinatorial libraries. Developments in the processes preceding and following synthesis are required to enable the flow of increased numbers of compounds without new bottlenecks developing. The impact of combinatorial chemistry will be greatly enhanced by synergy with ongoing parallel developments in genetic technologies, screening technologies and bioinformatics.

5.6.6 New Materials

The increasing complex needs of industry and society demand improved industrial processes and products with better quality, durability, cost effectiveness, functionality and structural properties. Furthermore, it is essential for environmental sustainability to examine all aspects of a product's life cycle to make substantial reductions in the use of resources while minimising environmental and health concerns. Therefore, materials research has an essential role in supporting development of competitive and sustainable growth.

New and improved product designs demand knowledge of the latest advanced materials. Having this knowledge and putting it into practice will frequently result in higher product performance, increased sales, and a more efficient manufacturing process. With the pace of technological development only quickening, choosing the right materials for a design can be a major factor in a product’s success or failure.

The most important areas of development include:

- Plastic Composites
- New Tougher Ceramics
- Intermetallics
- Metal Matrix Composites
- New Alloys

Advanced composite materials and structures consist of two or more materials combined in such a way that the individual materials are easily distinguishable. This includes:

- Structural polymer-matrix composites
- Metal-matrix composites
- Natural fibre composites
- Lightweight metal (e.g. steel or aluminum) in a sandwich structure

Polymer Development Trends

Polymer research will develop along the following lines in the years ahead:

- New analytical, physical and theoretical methods will steadily deepen our understanding of the relationships between polymer manufacture, structures and properties.
- New catalysts in association with innovative technologies will result in a shortening of the value-added chains; i.e. fewer finishing steps will be needed between cracker products and end polymers.
- The era of world-scale plants has passed its zenith. The future lies in miniaturizing world-scale capacities, i.e. in reactions with a high space-time yield.
- Even closer linkage between organic synthesis, catalysis, polymer chemistry, polymer physics, process technology, processing and application will accelerate the trend towards customized structure-molecule design.

New materials and production technologies

The increasing complex needs of industry and society demand improved industrial processes and products with better quality, durability, cost effectiveness, functionality and structural properties. Furthermore, it is essential for environmental sustainability to examine all aspects of a product's life cycle to make substantial reductions in the use of resources while minimising environmental and health concerns.

Materials properties and performance are closely linked to materials production and transformation. It is therefore important that materials research should also be closely integrated with work on materials processing.

Main technological objectives

Sustainable use of materials requires an integrated approach for optimum use of materials and increased recycling. Priorities are:

Crosscutting materials technologies

This involves developing novel materials with wide-ranging application potential. Such research can be long term with high risk and high potential gain, and includes:

- Nanotechnology: working at the nanoscale (1-100nm) with use of nano particles to improve properties in organic, biological and inorganic materials, and nano-structured materials for further miniaturisation of electronic systems

- Surface engineering: Expanding target materials and the range of coating properties
- Materials processing technologies: for multi-sector applications to improve performance of ceramics, polymers and metal alloys, coated materials and composites

Advanced functional materials

This is looking at highly advanced materials with multi-sector use, including:

- Electronics: focusing on novel electronic and opto-electronic devices
- Magnetic/optical materials: for magneto-resistive sensors and magnetic data storage
- Sensors and industrial systems: an important area for medium- and long-term development
- Biomaterials: for medical applications, including drug-delivery systems and biosensors.

Sustainable chemistry

This covers development of sustainable industrial chemistry with efficient use of resources and recycled materials, such as:

- Chemical engineering: particularly support for membranes and catalysts
- Advanced chemical reactions: especially small batches of speciality chemicals and polymers
- Chemistry for new materials: developing cost-effective, clean synthesis routes leading to high added-value materials with novel properties.

Structural materials

Structural materials cover all types of engineering needs - from civil engineering to aerospace.

Priorities include:

- Materials properties: to determine and extend the limits to open up novel and more efficient construction
- Reliability: with study of degradation mechanisms that limited material lifetimes
- Construction materials: to overcome the large amount of waste in an area of massive consumption.

5.6.7 The Process of Materials Engineering

New materials can often be critical enabling drivers for new systems and applications with significant effects. However, it may not be obvious how enabling materials affect more observable trends and applications. A common process model from materials engineering can help to show how materials appear likely to break previous barriers in the process that ultimately results in applications with potential global benefits.

Current trends in materials research that could result in global effects by 2015 are categorized below:

Concept/Materials Design

Biomimetics is the design of systems, materials, and their functionality to mimic nature. Current examples include layering of materials to achieve the hardness of an abalone shell or trying to understand why spider silk is stronger than steel.

Combinatorial materials design uses computing power (sometimes together with massive parallel experimentation) to screen many different materials possibilities to optimize properties for specific applications (e.g., catalysts, drugs, optical materials).

Materials Selection, Preparation, and Fabrication

Composites are combinations of metals, ceramics, polymers, and biological materials that allow multi-functional behavior. One common practice is reinforcing polymers or ceramics with ceramic fibers to increase strength while retaining light weight and avoiding the brittleness of the monolithic ceramic. Materials used in the body often combine biological and structural functions (e.g., the encapsulation of drugs).

Nanoscale materials, i.e., materials with properties that can be controlled at submicrometer ($<10^{-6}$ m) or nanometer (10^{-9} m) level, are an increasingly active area of research because properties in these size regimes are often fundamentally different from those of ordinary materials. Examples include carbon nanotubes, quantum dots, and biological molecules. These materials can be prepared either by purification methods or by tailored fabrication methods.

Processing, Properties, and Performance

These areas are inextricably linked to each other: Processing determines properties that in turn determine performance. Moreover, the sensitivity of instrumentation and measurement capability is often the enabling factor in optimizing processing, for example, as for nanotechnology and microelectromechanical systems (MEMS).

Rapid prototyping is the capability to combine computer-assisted design and manufacturing with rapid fabrication methods that allow inexpensive part production (as compared to the cost of a conventional production line). Rapid prototyping enables a company to test several different inexpensive prototypes before committing infrastructure investments to an approach. Combined with manufacturing system improvements to allow flexibility of approach and machinery, rapid prototyping can lead to an *agile manufacturing* capability. Alternatively, the company can use its virtual capability to design and then outsource product manufacturing, thus offloading capital investment and risk. This capability is synergistic with the information technology revolution in the sense that it is a further factor in globalizing manufacturing capability and enabling organizations with less capital to have a significant technological effect.

Self-assembly refers to the use in materials processing or fabrication of the tendency of some materials to organize themselves into ordered arrays (e.g., colloidal suspensions). This provides a means to achieve structured materials "from the bottom up" as opposed to using manufacturing or fabrication methods such as lithography, which is limited by the measurement and instrumentation capabilities of the day. For example, organic polymers have been tagged with dye molecules to form arrays with lattice spacing in the visible optical wavelength range and that can be changed through chemical means. This provides a material that fluoresces and changes color to indicate the presence of chemical species.

Manufacturing with DNA might represent the ultimate biomimetic manufacturing scheme. It consists of "functionalizing small inorganic building blocks with DNA and then using the molecular recognition processes associated with DNA to guide the assembly of those particles or building blocks into extended structures" (Mirkin, 2000 [106]). Using this approach, Mirkin and colleagues demonstrated a highly selective and sensitive DNA-based chemical assay method using 13 nm diameter gold particles with attached DNA sequences. This approach is compatible with the commonly used polymerase chain reaction (PCR) method of amplification of the amount of the target substance.

Micro- and nano-fabrication methods include, for example, lithography of coupled micro- or nano-scale devices on the same semiconductor or biological material. It is important to note the crucial role played in the development of these techniques by the parallel development of instrumentation and measurement devices such as the Atomic Force Microscope (AFM) and the various Scanning Probe Microscopes (SPMs).

Product/Application

The trends described above will likely work in concert to provide materials engineers with the capability to design and produce advanced materials that will be:

- Smart--Reactive materials combining sensors and actuators, perhaps together with computers, to enable response to environmental conditions and changes thereof. (Note, however, that limitations include the sensitivity of sensors, the performance of actuators, and the availability of power sources with required magnitude compatible with the desired size of the system.) An example might be robots that mimic insects or birds for applications such as space exploration, hazardous materials location and treatment, and unmanned aerial vehicles (UAVs).

- Multi-functional--MEMS and the "lab-on-a-chip" are excellent examples of systems that combine several functions. Another example is a drug delivery system using a hydrogel with hydrophilic exterior and hydrophobic interior. Consider also aircraft skins fabricated from radar-absorbing materials that incorporate avionic links and the ability to modify shape in response to airflow.

- Environmentally compatible or survivable--The development of composite materials and the ability to tailor materials at the atomic level will likely provide opportunities to make materials more compatible with the environments in which they will be used. Examples might include prosthetic devices that serve as templates for the growth of natural tissue and structural materials that strengthen during service (e.g., through temperature- or stress-induced phase changes).

Smart Materials

Several different types of materials exhibit sensing and actuation capabilities, including ferroelectrics (exhibiting strain in response to a electric field), shape-memory alloys (exhibiting phase transition-driven shape change in response to temperature change), and magnetostrictive materials (exhibiting strain in response to a magnetic field). These effects also work in reverse, so that these materials, separately or together, can be used to combine sensing and actuation in response to environmental conditions. They are currently in widespread use in applications from ink-jet printers to magnetic disk drives to anti-coagulant devices.

An important class of smart materials is composites based upon lead zirconate titanate (PZT) and related ferroelectric materials that allow increased sensitivity, multiple frequency response, and variable frequency (Newnham, 1997 [146]). An example is the "Moonie"--a PZT transducer placed inside a half-moon-shaped cavity, which provides substantial amplification of the response. Another example is the use of composites of barium strontium titanate and non-ferroelectric materials that provide frequency-agile and field-agile responses. Applications include sensors and actuators that can change their frequency either to match a signal or to encode a signal. Ferroelectrics are already in use as nonvolatile memory elements for smart cards and as active elements in smart skis that change shape in response to stress.

Another important class of materials is smart polymers (e.g., ionic gels that deform in response to electric fields). Such electro-active polymers have already been used to make "artificial muscles" (Shahinpoor et al., 1998 [147]). Currently available materials have limited mechanical power, but this is an active research area with potential applications to robots for space exploration, hazardous duty of various types, and surveillance. Hydrogels that swell and shrink in response to changes in pH or temperature are another possibility; these hydrogels could be used to deliver encapsulated drugs in response to changes in body chemistry (e.g., insulin delivery based upon glucose concentration). Another variation on this trend for controlled release of drugs is materials with hydrophilic exterior and hydrophobic interior.

Broader Issues and Implications

A world with pervasive, networked sensors and actuators (e.g., on and part of walls, clothing, appliances, vehicles, and the environment) promises to improve, optimize, and customize the capability of systems and devices through availability of information and more direct actuation.

Continuously available communication capability, ability to catalog and locate tagged personal items, and coordination of support functions have been espoused as benefits that may begin to be realized by 2015.

The continued development of small, low-profile biometric sensors, coupled with research on voice, handwriting, and fingerprint recognition, could provide effective personal security systems. These could be used for identification by police/military and also in business, personal, and leisure applications. Combined with today's information technologies, such uses could help resolve nagging security and privacy concerns while enabling other applications such as improved handgun safety (through owner identification locks) and vehicle theft control.

Other potential applications of smart materials that would be enabled by 2015 include: clothes that respond to weather, interface with information systems, monitor vital signs, deliver medicines, and automatically protect wounds; airfoils that respond to airflow; buildings that adjust to the weather; bridges and roads that sense and repair cracks; kitchens that cook with wireless instructions; virtual reality telephones and entertainment centers; and personal medical diagnostics (perhaps interfaced directly with medical care centers). The level of development and integration of these technologies into everyday life will probably depend more on consumer attitudes than on technical developments.

In addition to the surveillance and identification functions mentioned under smart materials above, developments in robotics may provide new and more sensitive capabilities for detecting and destroying explosives and contraband materials and for operating in hazardous environments. Increases in materials performance, both for power sources and for sensing and actuation, as well as integration of these functions with computing power, could enable these applications.

Such trend potentials are not without issues. Pervasive sensory information and access to collected data raise significant privacy concerns. Also, the pace of development will likely depend on investment levels and market drivers. In many cases the immediate benefits and cost savings from smart material applications will continue to drive development, but more exotic materials research may depend on public commitment to research and belief in investing in longer-term rewards.

Self-Assembly

Examples of self-assembling materials include colloidal crystal arrays with mesoscale (50-500 nm) lattice constants that form optical diffraction gratings, and thus change color as the array swells in response to heat or chemical changes. In the case of a hydrogel with an attached side group that has molecular recognition capability, this is a chemical sensor. Self-assembling colloidal suspensions have been used to form a light-emitting diode (nanoscale), a porous metal array (by deposition followed by removal of the colloidal substrate), and a molecular computer switch.

The DNA-based self-assembly mentioned above (Mirkin, 2000 [106]) was achieved by attaching non-linking DNA strands to metal nanoparticles and adding a linking agent to form a DNA lattice. This can be turned into a biosensor or a nanolithography technique for biomolecules.

Broader Issues and Implications

Development of self-assembly methods could ultimately provide a challenge to top-down lithography approaches and molecular manufacturing approaches. As a result, it could define the next manufacturing methodology at some time beyond 2015. For example, will self-assembly methods "trump" lithography (the miracle technology of the semiconductor revolution) over the next decade or two?

Rapid Prototyping

This manufacturing approach integrates computer-aided design (CAD) with rapid forming techniques to rapidly create a prototype (sometimes with embedded sensors) that can be used to visualize or test the part before making the investment in tooling required for a production run. Originally, the prototypes were made of plastic or ceramic materials and were not functional models, but now the capability exists to make a functional part, e.g., out of titanium. See, for example, the discussion of reverse-engineered bones in the section on biomedical engineering.

Broader Issues and Implications

As discussed above, agile manufacturing systems are envisioned that can connect the customer to the product throughout its life cycle and enable global business enterprises. An order would be processed using a computer-aided design, the manufacturing system would be configured in real time for the specific product (e.g., model, style, color, and options), raw materials and components would be acquired just in time, and the product would be delivered and tracked throughout its life cycle (including maintenance and recycling with identification of the customer). Components of the business enterprise could be dynamically based in the most cost-effective locations with all networked together globally. The growth of this type of business enterprise could accelerate business globalization.

New Materials

Materials research may provide improvements in properties by 2015 in a number of additional areas, leading to significant effects.

SiC, GaN, and other wide band gap semiconductors are being investigated as materials for high-power electronics.

Functionally graded materials (i.e., materials whose properties change gradually from one end to the other) can form useful interlayers between mechanically, thermally, or electrically diverse components.

Anodes, cathodes, and electrolytes with higher capacity and longer lifetime are being developed for improved batteries and fuel cells.

High-temperature (ceramic) superconductors discovered in 1986 can currently operate at liquid nitrogen (rather than liquid helium) temperatures. Prototype devices such as electrical transmission cables, transformers, storage devices, motors, and fault current limiters have now been built and demonstrated. Niche application on electric utility systems should begin by 2015 (e.g., replacement of underground cables in cities and replacement of older substation transformers).

Nonlinear optical materials such as doped LiNbO3 are being investigated for ultraviolet lasers (e.g., to enable finer lithography). Efforts are under way to increase damage threshold and conversion efficiency, minimize divergence, and tailor the absorption edge.

Hard materials such as nanocrystalline coatings and diamonds are being developed for applications such as computer disk drives and drill bits for oil and gas exploration, respectively.

High-temperature materials such as ductile intermetallics and ceramic matrix composites are being developed for aerospace applications and for high-efficiency energy and petrochemical conversion systems.

Nanomaterials

This area combines nanotechnology and many applications of nanostructured materials. One important research area is the formation of semiconductor "quantum dots" (i.e., several nanometer-size, faceted crystals) by injecting precursor materials conventionally used for chemical-vapor deposition of semiconductors into a hot liquid surfactant. This "quantum dot" is in reality a macromolecule because it is coated with a monolayer of the surfactant, preventing agglomeration. These materials photoluminesce at different frequencies (colors) depending upon their size, allowing optical multiplexing in biological labeling.

Another important class of nanomaterials is nanotubes (the open cylindrical sisters of fullerenes). Possible applications are field-emission displays (Mitsubishi research), nanoscale wires for batteries, storage of Li or H_2, and thermal management (heat pipes or insulation--the latter taking advantage of the anisotropy of thermal conductivity along and perpendicular to the tube axis). Another possibility is to use nanotubes (or fibers built from them) as reinforcement for composite materials. Presumably because of the nature of the bonding, it is predicted that nanotube-based material could be 50 to 100 times stronger than steel at one-sixth of the weight if current technical barriers can be overcome (Smalley, 1999; Service, 2000 [155, 161]).

Nanoscale structures with desirable mechanical and other properties may also be obtained through processing. Examples include strengthening of alloys with nanoscale grain structure, increased ductility of metals with multi-phase nanoscale microstructure, and increased flame retardancy of plastic nanocomposites.

5.6.8 Chemical Measurement

Real-time measurement tools Separation systems (e.g., plasma, microwave, photochemical, biochemical, supercritical, cryogenic, reactive extraction and distillation, and membrane reactors High-performance spectrometers

5.6.9 Computational Technologies

Computational molecular science, computational fluid dynamics (CFD), process modeling, simulation, operations optimization, and control.

Table 20: Important Research and Technology Areas across the Chemicals Industry

	ANALYTICAL	BIOTECHNOLOGY	CATALYSIS	CELL BIOLOGY	CHEM & BIOINFORMATICS	CHIRAL	COMBINATORIAL CHEM.	ENVIRONMENTAL	FORMULATION	MANUFACTURING & PROCESS CHEMISTRY	MATERIALS CHEMISTRY	MICROSYSTEMS	NANOTECHNOLOGY	ORGANIC CHEMISTRY	POLYMER CHEMISTRY	PROCESS INTENSIFICATION	SEPERATIONS
Pharmaceuticals	X	X	X	X	X	X	X	X	X	X		X	X	X		X	X
Specialised Organics	X	X	X			X	X	X	X	X		X	X	X	X	X	X
Dyes & Pigments	X							X	X	X			X				
Coatings, paints & ink	X	X						X		X	X		X	X	X		
Rubber								X	X		X				X		
Plastis & polymers		X	X			X		X		X	X			X	X		
Man-made fibres		X	X					X			X			X	X		
Petrochemicals & fuelstocks	X	X	X							X			X		X	X	X
Cleaning products		X	X					X	X	X			X		X		
Cosmetics & toiletries	X	X	X	X	X			X		X			X				
Inorganics	X					X		X	X	X	X		X				X
Chloralkali	X							X		X							X
Gases	X							X		X	X						X
Nuclear	X							X		X	x						X
Fertilisers								X	X	X							
Agrochemicals		x	X	x	x		X	X	X	X		x		x		x	

5.7 Profile of the South African Chemical Industry

The South African chemical industry constitutes 25% of manufacturing GDP, which in turn constitute 25% of the total national GDP (i.e. 6% of GDP). It is therefore an important sector, and its fortunes, or lack thereof, have a major impact on the overall performance of the country’s economy.

A more detailed review of the sector follows.

5.7.1 Sub-sectors of the Chemical Industry

The largest sector is liquid fuels followed by plastics conversion and pharmaceuticals.

The import dependence of some sectors is high and these are invariably the more specialised and therefore higher value chemicals.

It is interesting to note firstly the relative value of the contribution of each subsector to South Africa's GDP, and secondly South Africa's relative position in world production (Figure 1).

Given that South Africa's GDP is about 0,7% of global GDP, it is noted that three sectors (fuels, bulk formulated chemicals and pharmaceuticals) have a larger output than may be expected based on our GDP. It could also be speculated that South Africa has some advantage in these subsectors.

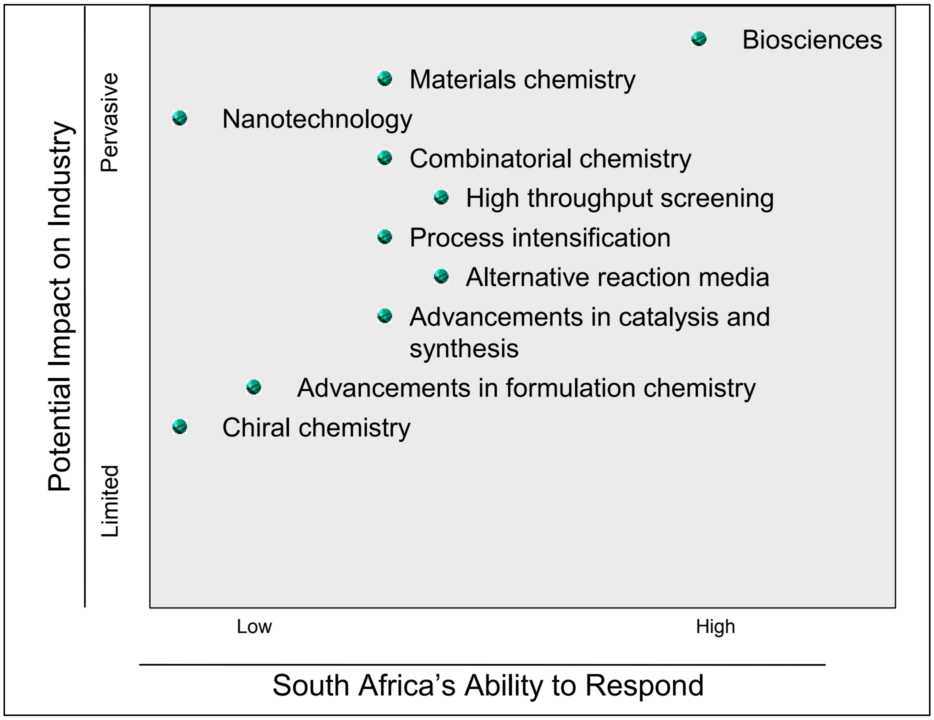
The comparative data are perhaps more useful in identifying potential growth areas. For instance, the fine chemicals sub-sector is small on both a national and an international scale. This is a concern, given the number of initiatives to stimulate local fine chemicals production, and reflects the general problems of downstream development of upstream import parity pricing, a small local market and lack of clear value-addition opportunities. In the context of the growing dominance by Indian and Chinese producers, it can also be argued that the opportunity to establish such an industry in South Africa has passed.

South Africa has a weak balance of payments position within the sector. This is because the exports are principally low-unit value commodity chemicals whereas imports are higher-value speciality chemicals. In some notable cases, South Africa exports low-quality materials and at the same time imports higher grades of exactly the same material.

5.7.2 South Africa's position with regards to new technologies

A small group of industry experts were questioned about the relevance of the globally identified technologies to understand if they pose any opportunities or threats to the South African chemicals industry.

Figure 9: Impact analysis grid



The general feedback from South African experts was that most of these technologies are fisrt world technologies, they are complex, expensive, require PHD to understand sometimes still at development stage. These technologies will impact the South African markets if they become dominant internationally. What is more important is that the chemicals sector focus on the established areas of excellence and available resources, starting with the opportunities where strong local markets exist.

South Africa is seen as having a number of competitive advantages including:

- Low energy costs, though whether this is sustainable in the longer term needs to be evaluated.
- Abundant coal, certain inorganic materials and natural products (all of which are key raw materials).
- Pockets of world-class technology (such as fuel from coal).
- Access to a unique slate of chemical intermediates from organisations such as NECSA and Sasol.
- Several world-class tertiary institutions that match their first world counterparts.

There are also a number of obvious weaknesses in the industry, which include the following:

- Upstream dominance with limited downstream integration and value addition.
- Absence of a local producer of aromatic chemicals (the so-called benzene, toluene and xylene (BTX) fraction, which are a key raw material for many polymers and speciality chemicals).
- An industry that is located mainly inland, and hence has the disadvantage of an inefficient transport infrastructure and high transport costs to the major international markets.
- For many chemicals, the sector is unable to take advantage of South Africa's strategic position in natural resources because the producers adopt the commercially advantageous practice of import parity pricing. This effectively penalises downstream companies to the benefit of the primary producers.
- A key weakness in the South African sector is the shortage of a well-trained and competent new generation of scientists and engineers entering the market. 35% of recent applications to the National Research Foundation for R&D funds for catalysis, supercritical fluid extraction, separation membrane techniques and nanomaterials came from A-rated scientists in the over-55 age bracket.

Notwithstanding the above problems, there are a number of existing and growing advantages for the industry, including:

- The availability of a new range of low-cost intermediates (such as linear alkenes) from the increasing use of GTL technology by Sasol.
- There is a strong view that the commodity inorganics as a sub-sector has significant and untapped potential. For instance, South Africa has a strong position in fluorine technology based on significant reserves of fluorspar and rock phosphate deposits, coupled with technology developed at NECSA.
- Less than 2% of South Africa's sugar production (2,5 m tons) is converted into biochemicals (such as lysine). The National Biotechnology Strategy is an attempt to address the technology needs of additional biochemical facilities.
- The country has a high level of biodiversity which, combined with a global swing towards natural products where demand exceeds supply, has created a major opportunity to capitalise on this wealth of diversity. Rooibos is a success story but there are many other possibilities including buchu and honeybush. A great deal of technology and research expenditure may be required to find the new chemical entities that could lead to future economic opportunity.

- Failure rates in the drug development pipelines of large pharmaceutical companies has created an opportunity for small companies to provide leads that have already passed through early, though less onerous, selection hurdles but which now require more substantial financial I investment than is realistically available locally.

- South Africa has the capability to develop generic drugs, thus reducing dependence on costly imports. There is also a need for vaccines for Third World conditions (malaria, cholera, etc.) without First World price tags. South Africa has shown early success in taking drugs off licence and repackaging them successfully and re-patenting them.

The recent AMTS project identified key areas that should be further developed to capatilise on the industry's strengths and market demand.

The CSTT has identified a number of such interventions that are considered to have a major potential benefit for the local industry, including:

- Development of a new industry based on the extraction of minerals from coal ash and low-value slag.

- Extension of NECSA's expertise in fluorine generation and use in order to generate a range of fluorinated organic chemical intermediates.

- Development of a new range of performance chemicals that will improve the recovery of minerals in the mining sector (such as polymer used in solvent extraction processes).

- Establishment of a new technology platform that will develop technologies to decrease economies of scale for chemical plants and hence enable smaller production facilities to compete against the mega plants.

- Support for existing development efforts in low-cost diagnostics, aroma chemicals production, development of biodegradable and high-performance polymers, bio-diesel and products from alpha-olefins.

- A major initiative to build South Africa's first generic pharmaceutical actives plant in order to meet future demand for antibiotics and/or anti-retrovirals.

- A highly integrated strategy to fully develop South Africa's ability to add maximum value to its natural products and unique biodiversity.

It is recommended that further investigation and selection of technologies for development be done in coherence with the CAIA and appropriate stakeholders and forums such as the upcoming Chemicals Industry Summit.

5.8 Government Support

5.8.1 Case study of the Chemical Industry in Sweden

General market information

The Swedish chemical industry has been internationally active for more than a century. The famous Swedish inventor Alfred Nobel, one of Sweden's original entrepreneurs, built his first nitro-glycerine factory in 1864. In less than 15 years, factories based on his technology were established in many countries, including the U S A. Nobel's great commercial success in the production of new types of explosives led to great personal wealth which to this day funds the Nobel prizes.

International, willing to invest and research intense characterises the Swedish Chemical Industry. The extensive investments made in chemical production sites in Sweden is now paying of, the production statistics shows an increase since early 90-s.

In 2002 the chemical industry in Sweden had a total turnover of 142 billion SEK (approx. 10.7 billion GBP (1 GBP=13.30)), whereof approx. a third is pharmaceuticals. Companies manufacturing chemical substances, used within processing industry or used a raw material, has a turnover of approx. 44 billion SEK. More than 50 percent of this is exported and equally divided between EU market and other markets.

According to the Swedish regulatory authority Kemikalieinspektionen, there are 60.000 products at the Swedish market, built up from 11.500 substances of which only 260 substances are manufactured in Sweden.

The industry has a total of 63.300 employees. This is 9 % of all employees working within Swedish manufacturing industries.

Foreign interest

The majority of Swedish manufacturers are exporting internationally. In total the chemical industry exports 83 billion SEK, which is 11 % of Sweden's total export. The chemical industry is Sweden's third largest industry. Overseas companies own the majority of Swedish companies, again giving an international dimension.

Significant investments

In average, chemical industry is investing 4 times more per employee in research and development than other Swedish industries. Also the average competence level is significantly higher than other industries. In the chemical industry there are five times more qualified researchers than in other industries.

In 2002, 10 billion SEK was invested in chemical industry. Approx. 50 % is within pharmaceuticals, and one third is within basic chemical industry.

The chemical industry and environmental problems

As to fulfilling environmental targets set by laws and regulations, the chemical industry is a "key" branch also in the sense that it is able to solve pollution problems - both emissions and waste - not only within the chemical industry itself, but also for other industries and for the public sector. Research and development undertaken or sponsored by chemical enterprises have resulted in the marketing of new, more efficient and economically viable water treatment chemicals, catalysts for car exhausts, of adsorbent materials for the treatment of air pollution (zeolites) and also in new systems for bleaching of pulp without the use of elementary chlorine etc.

Chemical sewage and treatment plants were introduced on a large scale in Swedish municipalities as early as in the beginning of the 1970s, giving the Swedish chemical industry a lead in the development of water treatment chemicals.

The Chemical industry in Sweden has a long tradition of working with continuous improvements of its environmental performance. Already in 1991 Responsible Care, the chemical industry's commitment to continual improvement in all aspects of health, safety and environment performance and to openly communicate its activities, achievements, plans and targets, was introduced in Sweden. The Association of Swedish Chemical Industries supports member companies in their work with Responsible Care. As of today more than 115 companies are participating in the Responsible Care program.

The fact that many Swedish chemical industries already have adopted environmental management systems according to ISO 14001 and/or EMAS can also illustrate the importance paid to environmental matters. In addition to this a great number of companies are in the process of introducing such systems.

Technology and Research

The chemical industry puts a premium on technical know-how and research. No other industrial branch in Sweden employs as many graduated scientists. Earlier heydays in the history of Swedish chemistry were the result of brilliant research by C W Scheele (1742-1786), J J Berzelius (1779-1848) and A Nobel (1833-1896). Ingenious, gifted and creative scientists have been of great importance for the rapid development of the Swedish chemical industry.

The chemical industry counts for approximately 22 % of the total research and development (R&D) in Sweden. The total number of employees in the R&D sector in the chemical industry is 6 195 compared to the total number of 37 500 in the chemical industry, which is 17 % of the total industry. Chemical industry in general and pharmaceutical industry in particular has considerably increased the R&D activities. In 1999 the total R&D costs in the chemical industry in Sweden amounted to MSEK 10 330, out of which as much as MSEK 9 000 was spent by the pharmaceutical industry. The R&D expenditures in the pharmaceutical industry related to the sales value is 24 %, which can be compared to the overall industry of 4 %.

In the last few years the companies, including the small and medium-sized enterprises (SME) has become more interested to establish close contact with the chemical institutions at the universities and institutes of technology. A new project of R&D in small and medium-sized companies has been established in 1999 to support and give ten university graduates the possibility to study for a doctor's degree in six different companies. The projects are established in close co-operation with four different academies, the University of Gothenburg, Chalmers University of Technology, University of Technology in Lund and the University of Karlstad.

Innovation companies are mostly located in "technical parks" close to the Institutes of Technology in Gothenburg, Lund and Stockholm, namely Chalmers Teknikpark, Ideon and Teknikhöjden, respectively.

The number of biochemical industries has increased tremendously the last years in the areas of Lund, Uppsala and Gothenburg.

BIOTECHNOLOGY SECTOR

6 TECHNOLOGY DEVELOPMENT TRENDS OF BIOTECHNOLOGY SECTOR

Definition of Biotechnology

Biotechnology is the application of molecular and cellular processes to solve problems, conduct research, and create goods and services. Under this definition, biotechnology includes a diverse collection of technologies that manipulate cellular, subcellular, or molecular components in living things to make products, discover new knowledge about the molecular and genetic basis of life, or modify plants, animals, and microorganisms to carry desired traits. The hallmark of biotechnology is cellular and genetic techniques that manipulate cellular and subcellular building blocks for applications in various scientific fields and industries such as medicine, animal health, agriculture, marine life, and environmental management.

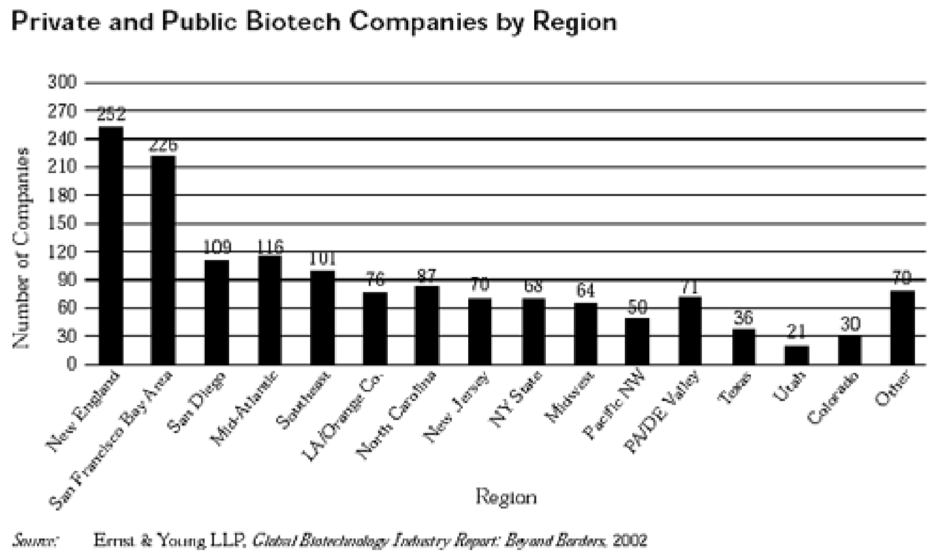
6.1 South Africa's Position

South Africa recognises the role of biotechnology in economic development with the government's adoption of the draft National Biotechnology Strategy in 2001, which commits over R400 million to the further development of biotechnology, and in particular a bioeconomy in the country. To date, South Africa has only a very small bioeconomy, although biotechnologies are widely used in a number of industrial sectors including food and beverage, and waste water treatment. The emphasis in South Africa is still at the R&D level, the application of a new set of technologies and the application of the technology tools by defined sectors.

South Africa has been involved with biotechnology research and development for over 20 years. Plant trials have been carried out under interim and new legislation for over 10 years. In 1998 there were approximately 110 groups, participating in 160 projects, from both academic and research institutions that were active in plant biotechnology. It was estimated that 45 companies were using biotechnology in food, feed and fibre. In all, there were over 500 biotechnology projects spread across seven sectors (biosafety, chemical, environmental, food, medical/pharmaceutical, plant, veterinary) in South Africa. The medical and pharmaceutical sector attracted the most research funding while the plant sector attracts the second largest amount.[2] It should be noted that few local products are developed, in spite of the 20 years of research and development. The sector is heavily dependent on imported technology, which is driving commercialisation and industrial growth. This is reflected in relatively low levels of local technology innovation.

[2] Webster and Koch (1998). Biotechnology Survey: A Situational Analysis of South Africa and Sub-Saharan Africa. CSIR internal report.

Figure 10: Private and Public Biotech Companies by regions



6.2 Biotechnology Trends

Genetics: The genomics revolution is generating tremendous opportunities and challenges for the biotech, pharmaceutical and health services industries. Most observers had expected the sequencing of the human genome to take 8–10 years; yet in a move evoking the biotech equivalent of Moore's Law, not only is the sequencing complete, but powerful new technologies are poised to revolutionize and redefine the drug discovery process and, eventually, the financing and delivery of health services.

In addition to genomics, emerging technologies such as, proteomics, biochips, signal transduction and toxicogenomics are changing the drug discovery landscape and creating new opportunities for pharmaceutical, biotechnology and other health-related companies.

Biofactories: The industrial use of plants and animals to produce functionally specific biomolecules that serve to enhance food, feedstock, and biopharmaceutical quality.

Biosensors: Devices combining the extreme selectivity qualities of living systems for expanding the use of biological, medical, behavioural or health data.

Biomaterials: The study and use of both living tissue and artificial materials to promote healing and regeneration.

Bioinformatics: Research, development, or application of computational tools and approaches for expanding the use of biological, medical, behavioural or health data.

Biophotonics: Photon-based experimental manipulation and advanced optical imaging applied to the biotech sector.

Nanobiotechnology: Developing technologies at the nano-scale (10-9) for biological applications.

Proteomics: The study of protein sequence, structure, function and interaction.

Medical Robotics: Development of robotic technologies for medical applications.

Biometrics: The application of statistical and mathematical methods to biological data analysis with applications for identification.

Bioremediation: The application of micro-organisms or products to remove or degrade environmental contaminants.

Bioproducts: Industrial or commercial [i]products developed from the agriculture, forestry and aquaculture sectors.

6.3 Technologies, Applications and Implications

Bioprocessing Technology

The oldest of the biotechnologies, bioprocessing technology, uses living cells or the molecular components of their manufacturing machinery to produce desired products. The living cells most commonly used are one-celled microorganisms, such as yeast and bacteria; the biomolecular components are most often enzymes, which are proteins that catalyze biochemical reactions. *Microbial fermentation,* has been used for thousands of years to brew beer, make wine, leaven bread and pickle foods. The diverse manufacturing capability of naturally occurring microorganisms provide products such as antibiotics, birth control pills, amino acids, vitamins, industrial solvents, pigments, pesticides and food-processing aids.

Paralleling the evolution of biotechnology from old to new, "bioprocessing" gradually became "bioprocessing technology" as science uncovered the molecular details of cell processes. Scientists now use microbial fermentation, in conjunction with recombinant DNA technology, to manufacture products such as human insulin, the calf enzyme used in cheese-making, biodegradable plastics, laundry detergent enzymes and the hepatitis B vaccine.

Monoclonal Antibodies

Monoclonal antibody technology uses immune-system cells that make proteins called antibodies. The specificity of antibodies makes it a powerful *diagnostic tool.* They can locate substances that occur in minuscule amounts and measure them with great accuracy. For example, monoclonal antibodies are used to

- locate environmental pollutants.
- detect harmful miroorganisms in food.

- distinguish cancer cells from normal cells.
- diagnose infectious diseases in humans, animals and plants more quickly and more accurately than ever before.

In addition to their value as detection devices, monoclonal antibodies can provide highly specific therapeutic compounds. Monoclonal antibodies joined to a toxin can selectively deliver chemotherapy to a cancer cell while avoiding healthy cells. Scientists are developing monoclonal antibodies to treat organ-transplant rejection and autoimmune diseases by targeting them specifically to the type of immune system cell responsible for these attacks, leaving intact the other branches of the immune system.

Cell Culture

Cell culture technology is the growing of cells outside of living organisms.

Plant Cell Culture

An essential step in creating transgenic crops, plant cell culture is also providing an environmentally sound and economically feasible option for obtaining naturally occurring products with therapeutic value. Plant cell culture is also an important source of compounds used as flavors, colors and aromas by the food-processing industry.

Insect Cell Culture

Insect cell culture can broaden the use of biological control agents that kill insect pests without harming beneficial insects or having pesticides accumulate in the environment. Even though the environmental advantages of biological control have been recognized for many decades, manufacturing biological control products in marketable amounts has been impossible. Insect cell culture removes these manufacturing constraints. In addition, like plant cell culture, insect cell culture is being investigated as a production method of therapeutic proteins.

Mammalian Cell Culture

Lifestock breeding has used mammalian cell culture as an essential tool for decades. The use of mammalian cell culture now extends well beyond the brief maintenance of cells in culture for reproductive purposes. Mammalian cell culture is replacing animal testing to assess the safety and efficacy of medicines. Of similar importance is the manufacturing capacity of mammalian cells to synthesize therapeutic compounds, in particular, certain mammalian proteins too complex to be manufactured by genetically modified microorganisms. For example, monoclonal antibodies are produced through mammalian cell culture.

Therapies based on cultured *adult stem cells,* which are permanently immature cells produced by a few tissue types, are on the horizon as well. Healthy bone marrow cells, a type of adult stem cell that can become either white or red blood cells, have been used for years to treat some cancers. Certain diseases of other tissue types that produce adult stem cells, such as liver and muscle, might also be amenable to treatment by replacing diseased cells with healthy stem cells grown in culture.

However, most tissues do not have a continual supply of stem cells as a source of healthy cells. Researchers hope *embryonic stem cells,* which can become any type of cell in the human body, can serve as a source of healthy cells for tissues that lack their own stem cells. Such embryonic stem cells could be used to treat diabetes, Parkinson's disease and Alzheimer's disease, and to restore function to victims of strokes and heart attacks.

Cloning

Cloning technology allows enables the generation of a population of genetically identical molecules, cells, plants or animals. Because cloning technology can be used to produce molecules, cells, plants and some animals, its applications are extraordinarily broad.

Molecular Cloning

Molecular, or gene, cloning, the process of creating genetically identical DNA molecules, provides the foundation of the molecular biology revolution and is a fundamental and essential tool of biotechnology research, development and commercialization. Virtually all applications of recombinant DNA technology, from the Human Genome Project to pharmaceutical manufacturing to the production of transgenic crops, depend on molecular cloning.

In molecular cloning, the word *clone* refers to a gene or DNA fragment and also to the collection of cells or organisms, such as bacteria, containing the cloned piece of DNA. Because molecular cloning is such an essential tool of molecular biologists, in scientific circles "to clone" has become synonymous with inserting a new piece of DNA into an existing DNA molecule.

Cellular Cloning

Cellular cloning produces cell lines of identical cells and is also a fundamental tool of biotechnology research, development and product manufacturing. All these applications depend on producing genetically identical copies of cells: the therapeutics and diagnostic uses of monoclonal antibody technology; the regeneration of transgenic plants from single cells; pharmaceutical manufacturing based on mammalian cell culture; and generations of therapeutic cells and tissues, which is known as *therapeutic cloning.*

Animal Cloning

Animal cloning has incorporated improvements into livestock herds for more than two decades and has been an important tool for scientific researchers since the 1950s. Although the 1997 debut of Dolly, the cloned sheep, brought animal cloning into the public consciousness, the production of an animal clone was not a new development. Dolly was considered a scientific breakthrough not because she was a clone, but because the source of the genetic material that was used to produce Dolly was an adult cell, not an embryonic one.

Recombinant DNA technologies, in conjunction with animal cloning, is providing excellent animal models for studying genetic diseases, aging and cancer and, in the future, will assist with discovery of drugs and evaluate other forms of therapy, such as gene and cell therapy. Animal cloning provides zoo researchers with a tool for helping to save endangered species. In August 1998, for example, a rare breed of cow was cloned.

Recombinant DNA Technology

Recombinant DNA technology is one of the many genetic modification techniques developed over the centuries. In nature and in the lab, recombinant DNA is made by combining genetic material from different sources.

In addition to using selective breeding to combine valuable genetic material from different organisms, scientists now combine genes at the molecular level using the more precise techniques of recombinant DNA technology.

- Genetic modification through selective breeding and recombinant DNA techniques fundamentally resemble each other, but there are important differences:
- Genetic modification using recombinant DNA techniques allow moving single genes whose functions are known from one organism to any other.
- In selective breeding, large sets of genes of unknown function are transferred between related organisms.

By making our manipulations more precise and outcomes more certain, decreases the risk of producing organisms with unexpected traits and avoid the time-consuming, trial-and-error approach of selective breeding. Currently, recombinant DNA techniques are used, in conjunction with molecular cloning, to

- produce new medicines and safer vaccines.
- treat some genetic diseases.
- enhance biocontrol agents in agriculture.
- increase agricultural yields and decrease production costs.
- decrease allergy-producing characteristics of some foods.
- improve food’s nutritional value.
- develop biodegradable plastics.

- decrease water and air pollution.
- slow food spoilage.
- control viral diseases.
- inhibit inflammation.

Protein Engineering

Protein engineering technology will be used, often in conjunction with recombinant DNA techniques, to improve existing proteins, such as enzymes, antibodies and cell receptors, and to create proteins not found in nature. These proteins will be used in drug development, food processing and industrial manufacturing.

The most pervasive uses of protein engineering to date are applications that alter the catalytic properties of enzymes to develop ecologically sustainable industrial processes. Enzymes are environmentally superior to most other catalysts used in industrial manufacturing, because, as biocatalysts, they dissolve in water and work best at neutral pH and comparatively low temperatures. In addition, because biocatalysts are more specific than chemical catalysts, they also produce fewer unwanted byproducts. The chemical, textile, pharmaceutical, pulp and paper, food and feed, and energy industries are all benefiting from cleaner, more energy-efficient production made possible by incorporating biocatalysts into their production processes.

The characteristics that make biocatalysts environmentally advantageous may, however, limit their usefulness in certain industrial processes. For example, most enzymes fall apart at temperatures above 100° F. Scientists are circumventing these limitations by using protein engineering to increase enzyme stability under harsh manufacturing conditions.

In addition to industrial applications, medical researchers have used protein engineering to design novel proteins that can bind to and deactivate viruses and tumor-causing genes; create especially effective vaccines; and study the membrane receptor proteins that are so often the targets of pharmaceutical compounds. Food scientists are using protein engineering to improve the functionality of plant storage proteins and develop new proteins as gelling agents.

Biosensors

Biosensor technology couples knowledge of biology with advances in microelectronics. A biosensor is composed of a biological component, such as a cell, enzyme or antibody, linked to a tiny transducer — a device powered by one system that then supplies power (usually in another form) to a second system. Biosensors are detecting devices that rely on the specificity of cells and molecules to identify and measure substances at extremely low concentrations. (Specificity refers to the fact that biological molecules are designed so that they bind to only one molecule.)

When the substance of interest binds with the biological component, the transducer produces an electrical or optical signal proportional to the concentration of the substance. Biosensors can, for example,

- measure the nutritional value, freshness and safety of food.
- provide emergency room physicians with bedside measures of vital blood components.
- locate and measure environmental pollutants.
- detect and quantify explosives, toxins and biowarfare agents.

Bio-nanotechnology

Nanotechnology, which came into its own in 2000 with the birth of the National Nanotechnology Initiative, is the next stop in the miniaturization path that enabled microelectronics, microchips and microcircuits. The word *nanotechnology* derives from *nanometer*, which is one-thousandth of a micrometer (micron), or the approximate size of a single molecule. Nanotechnology — the study, manipulation and manufacture of ultra-small structures and machines made of as few as one molecule — was made possible by the development of microscopic tools for imaging and manipulating single molecules and measuring the electromagnetic forces between them.

Bio-nanotechnology joins the breakthroughs in nanotechnology to those in molecular biology. Molecular biologists help nanotechnologists understand and access the nanostructures and nanomachines designed by 4 billion years of engineering — cell machinery and biological molecules. Exploiting the extraordinary properties of biological molecules and cell processes, nanotechnologists can accomplish many goals that are difficult or impossible to achieve by other means.

For example, rather than build silicon scaffolding for nanostructures, DNA's ladder structure provides nanotechnologists with a natural framework for assembling nanostructures; and its highly specific bonding properties bring atoms together in a predictable pattern to create a nanostructure.

Nanotechnologists also rely on the self-assembling properties of biological molecules to create nanostructures, such as lipids that spontaneously form liquid crystals.

DNA has been used not only to build nanostructures but also as an essential component of nanomachines. Most appropriately, DNA, the information storage molecule, may serve as the basis of the next generation of computers. As microprocessors and microcircuits shrink to nanoprocessors and nanocircuits, DNA molecules mounted onto silicon chips may replace microchips with electron flow-channels etched in silicon. Such biochips are DNA-based processors that use DNA's extraordinary information storage capacity. Conceptually, they are very different from the DNA chips discussed below. Biochips exploit the properties of DNA to solve computational problems; in essence, they use DNA to do math. Scientists have shown that 1,000 DNA molecules can solve in four months computational problems that require a century for a computer to solve.

Other biological molecules are assisting in our continual quest to store and transmit more information in smaller places. For example, some researchers are using light-absorbing molecules, such as those found in our retinas, to increase the storage capacity of CDs a thousandfold.

Some more imminent applications of bio-nanotechnology include

- increasing the speed and power of disease diagnostics.
- creating bio-nanostructures for getting functional molecules into cells.
- improving the specificity and timing of drug delivery.
- miniaturizing biosensors by integrating the biological and electronic components into a single, minute component.
- encouraging the development of green manufacturing practices.

Microarrays

Microarray technology is transforming laboratory research because it enabled tens of thousands of samples simultaneously. A 2002 study estimates an annual compounded growth rate of 63 percent between 1999 and 2004, from $232 million (U.S.) to $2.6 billion.

Researchers currently use microarray technology mostly to study gene structure and function. Thousands of DNA or proteins molecules are arrayed on glass slides to create DNA chips and protein chips, respectively. Recent developments in microarray technology use customized beads in place of glass slides.

DNA Microarrays

DNA microarrays are being used to

- detect mutations in disease-causing genes.
- monitor gene activity.
- diagnose infectious diseases and identify the best antibiotic treatment.
- identify genes important to crop productivity.
- improve screening for microbes used in bioremediation.

DNA-based arrays will be essential for converting the raw genetic data provided by the Human Genome Project and other genome projects into useful products. Gene sequence and mapping data mean little until researchers determine what those genes do — which is where protein arrays come in.

While going from DNA arrays to protein arrays is a logical step, it is by no means simple to accomplish. The structures and functions of proteins are much more complicated than that of DNA, and proteins are less stable than DNA. Each cell type contains thousands of different proteins, some of which are unique to that cell's job. In addition, a cell's protein profile varies with its health, age, and current and past environmental conditions.

Protein Microarrays

Protein microarrays will be used to

- discover protein biomarkers that indicate disease stages.
- assess potential efficacy and toxicity of drugs before clinical trials.
- measure differential protein production across cell types and developmental stages, and in both healthy and diseased states.
- study the relationship between protein structure and function.
- assess differential protein expression in order to identify new drug leads.
- evaluate binding interactions between proteins and other molecules.

Microarray technology was developed originally for genetic analysis, but the fundamental principal underlying this technology has inspired researchers to create many types of microarrays to answer scientific questions and discover new products.

Tissue Microarrays

Tissue microarrays, which allow the analysis of thousands of tissue samples on a single glass slide, are being used to detect protein profiles in healthy and diseased tissues and validate potential drug targets. Brain tissue samples arrayed on slides with electrodes allow researchers to measure the electrical activity of nerve cells exposed to certain drugs.

Whole-Cell Microarrays

Whole-cell microarrays circumvent the problem of protein stability in protein microarrays and permit a more accurate analysis of protein interactions within a cell.

Small-Molecule Microarrays

Small-molecule microarrays allow pharmaceutical companies to screen ten of thousands of potential drug candidates simultaneously. Researchers are also using of three nucleotide bases (a codon) determines each of 22 amino acids. (Two more amino acids have been discovered since the first 20 were determined.)

6.4 Research Applications of Biotechnology

Because biotechnology is based on the use of cells and biological molecules, it stands to reason that research applications of the biotechnologies focus primarily on understanding cellular and molecular processes.

Researchers use biotechnology to gain insight into the precise details of cell processes: the specific tasks assigned to various cell types; the mechanics of cell division; the flow of materials in and out of cells; the path by which an undifferentiated cell becomes specialized; and the methods cells use to communicate with each other, coordinate their activities and respond to environmental changes.

Researchers dissect these processes into the smallest possible bits of useful information. This requires identifying the molecular players involved in each facet of the process, elucidating the nature of their interactions and discovering the molecular control mechanisms that govern these interactions. Once they have teased apart every detail of the process, they must then reassemble the pieces in a way that provides insight into the inner workings of cells and, ultimately, of whole organisms.

Interestingly, the tools of biotechnology have also become important research tools in many branches of science other than cell and molecular biology, such as chemistry, engineering, materials science, ecology, evolution and computer science. The biotech-driven discoveries in these fields help the industry and others discover and develop products, but they also help industries improve their performance in areas such as environmental stewardship and workplace safety.

Understanding Cell Processes

Current and future commercial applications of biotechnology require the capability to generate and maintain a ready and plentiful supply of various cell types and a detailed understanding of basic cell functions.

The large-scale production of therapeutic proteins relies on understanding the factors that control cell growth and replication as well as the basic requirements for keeping a large number of mammalian cells healthy and productive.

Cell Culture Technology

Researchers are keeping cells in culture to investigate the molecular basis of many cell processes, especially cell growth, proliferation, differentiation and death.

All cells progress through essentially the same cycle: They increase in size up to a certain point, the genetic material replicates, and the cell divides in two. Understanding what controls *the cell cycle* is essential to understanding the cause of many human and animal diseases, the basis of increasing crop plant yields, and a means for quickly increasing the yeast cells used to manufacture products as diverse as fermented foods and medicines.

Improvements in cell culture technology allows better understand the molecular basis of the cell cycle. The rigorously controlled sequence of steps in the cell cycle depends on both genetic and nutritional factors. A delicate balance exists between factors that stimulate cell division and those that inhibit it. Any disruption of this balance leads to uncontrolled cell proliferation — cancer — or cell death.

Stem Cell Culture and Cloning Technology

Researchers are making considerable progress in charting the path of a cell from a single, fertilized egg to a whole organism, a feat that has eluded them for decades. The development of a multicelled organism from a single cell involves cell proliferation and *cell differentiation* — groups of cells becoming specialized, or differentiated, to perform specific tasks. Cell differentiation is the process of turning off certain genes within a group of cells while turning on others. Scientists are optimistic about their elucidating the many steps in the differentiation pathway and identifying the external and internal factors regulating the process. The breakthroughs that gave birth to this optimism are the development of a protocol for maintaining human stem cells in culture and the birth of the cloned sheep Dolly.

Maintaining cultures of stem cells can provide answers to critical questions about cell differentiation: What factors determine the ultimate fate of unspecialized stem cells? How plastic are adult stem cells? Could ASC be converted into an ESC with the right combination of factors? Why do stem cells retain the potential to replicate indefinitely? Is the factor that allows continual proliferation of ESCs the same factor that causes uncontrolled proliferation of cancer cells? If so, will transplanted ESCs cause cancer?

Understanding Gene Function

The cell processes described above — growth, proliferation, differentiation, apoptosis — and many more are carried out and controlled by proteins. Proteins are the molecular players that drive each minute step and regulate the overall process.

Understanding the nitty-gritty details of cell processes in health and disease means understanding proteins. Because genes contain the information for making proteins, understanding proteins means understanding gene function. The tools of biotechnology give scientists myriad opportunities to study gene function. Here are only a few of the ways biotechnology allows investigators to probe the genetic basis of cell functions.

Molecular Cloning

Either directly or indirectly, molecular cloning has been the primary driving force of the biotechnology revolution and has made remarkable discoveries routine. T he research findings made possible through molecular cloning include identifying, localizing and characterizing genes; creating genetic maps and sequencing entire genomes; associating genes with traits and determining the molecular basis of the trait.

Molecular cloning involves inserting a new piece of DNA into a cell in such a way that it can be maintained, replicated and studied. To maintain the new DNA fragment, scientists insert it into a circular piece of DNA called a plasmid that protects the new fragment from the DNA-degrading enzymes found in all cells. Because a piece of DNA is inserted, or recombined with, plasmid DNA, molecular cloning is a type of recombinant DNA technology.

The new DNA, now part of a recombinant molecule, replicates every time the cell divides. In molecular cloning, the word *clone* can refer to the new piece of DNA, the plasmid containing the new DNA and the collection of cells or organisms, such as bacteria, containing the new piece of DNA. Because cell division increases, or "amplifies," the amount of available DNA, molecular cloning provides researchers with an unlimited amount of a specific piece of genetic material to manipulate and study.

In addition to generating many copies of identical bits of genetic material, molecular cloning also enables scientists to divide genomes into manageable sizes. Even the simplest genome — the total genetic material in an organism — is too cumbersome for investigations of single genes. To create packages of genetic material of sizes that are more amenable to studies such as gene sequencing and mapping, scientists divide genomes into thousands of pieces and insert each piece into different cells. This collection of cells containing an organism's entire genome is known as a *DNA library.* Because identifying and mapping genes relies on DNA libraries created with molecular cloning, "to clone" can also mean to identify and map a gene.

One of the primary applications of molecular cloning is to identify the protein product of a particular gene and to associate that protein with the appearance of a certain trait. While this is useful for answering certain questions, genes do not act in isolation of one another. To truly understand gene function, one need to monitor the activity of many genes simultaneously. Microarray technology provides this capability.

Microarray Technology

Researchers can now gain a richer appreciation of gene function because microarray technology allows them to monitor the expression of hundreds or thousands of genes at one time. Recently, a 12,000-gene microarray allowed researchers to identify the 200 or so genes that, based on their gene expression profiles, distinguish stem cells from differentiated cells.

Monitoring simultaneous changes in gene function will shed light on many basic biological functions. Microarrays that display various tissue types allow scientists to determine the different genes that are active in different tissues. Simply being able to link an active gene to a tissue type can clue researchers in on its function. For example, a plant gene active in leaves but not roots or seeds may be involved in photosynthesis.

Different environmental conditions also affect gene expression. Researchers subject plants to stresses such as cold and drought, and then they use microarray technology to identify the genes that respond by initiating protein production. Researchers are also comparing gene activities of microbes that live in environments contaminated with pollutants to others that live in pristine environments to identify genes that break down environmental contaminants.

Antisense and RNA Interference

Another approach to understanding the relationship between genes, proteins and traits involves blocking gene expression and measuring resulting biochemical or visible changes. Scientists use antisense technology to block genes selectively. Antisense molecules are small pieces of DNA (or, more often, its close relative, RNA) that prevent production of the protein encoded in the blocked DNA.

A related, but mechanistically different method of silencing genes is known as RNA interference. Antisense technology works by using a single strand of DNA or RNA to physically block protein production from the RNA template. In RNA interference, adding small, double-stranded pieces of RNA to a cell triggers a process that ends with the enzymatic degradation of the RNA template. RNA interference, which was discovered serendipitously in plants in the 1990s, appears to be a natural mechanism that virtually all organisms use to defend their genomes from invasion by viruses.

Precisely blocking the functions of single genes to assess gene function can provide important insights into cell processes. Most cell processes are structured as pathways that consist of small biochemical steps. Sometimes the pathway resembles a chain reaction and consists of a complex cascade of events caused by one protein causing changes in another protein. At other times, the pathway is a sequence of enzyme-catalyzed reactions in which each enzyme (protein) changes a molecule slightly and then hands it off to the next enzyme. The manifestation of a certain trait or disease is the culmination of all these steps.

Certain techniques provide information on the proteins involved in these processes. While this information is useful, the key to understanding the process is determining the precise sequence of events. Sequential events in a pathway can be elucidated by selectively blocking or knocking out single genes and identifying the protein that is not produced.

Animal Cloning and Gene Knockouts

One of biotech's most powerful research tools for elucidating gene function is targeted mutations, or gene knockouts. By deleting or disrupting specific genes in cells, valuable information about the role a given gene plays in the expression of a certain protein can be obtained. When gene-knockout technology is combined with the ability to derive genetically identical animals from cultured cells, one can determine how the absence of this protein affects the whole organism.

Putting the Pieces Together: 'Omics'

The only way to truly understand organisms is to reassemble these bits and pieces into systems and networks that interact with each other. This need to assemble separate findings into a complete picture has given birth to a rash of "omics": genomics, proteomics, metabolomics, immunomics, transcriptomics. These research avenues attempt to integrate information into whole systems and not focus on the individual components in isolation from each other. The biotechnologies are important tools in these endeavors, but the information technologies are essential for integrating molecular data into a coherent whole.

While the research discoveries described above were provided primarily by academic and government scientists, private sector researchers, especially those in small biotechnology companies, are joining the public sector scientists in research designed to integrate the basic research findings. The fields of research described below bridge scientific discoveries in cellular and molecular biology with their commercial applications.

Genomics

Genomics is the scientific study of the genome and the role genes play, individually and collectively, in determining structure, directing growth and development, and controlling biological functions. It consists of two branches: structural genomics and functional genomics.

Structural Genomics

The field of structural genomics focuses on the physical aspect of the genome and includes the construction and comparison of various types of genome maps and large-scale DNA sequencing. In addition to genome mapping and sequencing, the objective of structural genomics research is gene discovery, localization and characterization.

Private and public structural genomics projects have generated genome maps and complete DNA sequences for many organisms, including crop plants and their pathogens, disease-causing bacteria and viruses, yeast that are essential to the food processing and brewing industries, nitrogen-fixing bacteria, the malaria parasite and the mosquito that transmits it, and the microbes one use to produce a wide variety of industrial products.

Knowing the complete or partial DNA sequences of certain genes or markers can provide researchers with useful information, even if the precise details of gene function remain unknown. For example, sequence data alone can

- help plant breeders follow specific traits in a breeding program and test for inheritance without having to rear the plants to reproductive maturity.
- be used to isolate specific recombinant molecules or microbes with unique biochemistry.
- identify the genes involved in complex traits that are controlled by many genes and those that have an environmental component.
- detect microbial contaminants in cell cultures.

Functional Genomics

While sequencing entire genomes, discovering genes and mapping them are truly remarkable achievements, they represent only the first milestone in the upcoming genomics revolution. This field of study, known as functional genomics, translate the data amassed from structural genomics into biological functions.

Scores of genes usually contribute to the appearance of a visible trait, and the biotechnologies now permit analysis of all of the relevant genes and assess the nature and timing of their involvement. They also allow researchers to discover genes involved in traits that have no visible or measurable manifestation. In addition, even though every cell of an organism has the same genetic material throughout its life, the activity of the ever-constant genetic material varies continually. Thousands of genes in a single tissue type toggle on and off at different developmental stages, in health and disease, at different ages and in response to environmental variation. Functional genomics provides insight into all the genes involved and the roles they play.

Proteomics

Each cell produces thousands of proteins, each with a specific function. This collection of proteins in a cell is known as its proteome, and proteomics is the study of the structure, function, location and interaction of proteins within and between cells.

Functional genomics can be used to answer certain questions about gene function without ever having to delve into the world of proteins. However, the path from the gene to a trait is paved with many proteins. Genes exert their effects through proteins; gene expression is protein production. Ultimately, structural genomics, functional genomics and proteomics must be combined to fully comprehend the relationship between genes, protein production and traits. And yet, proteomics presents researchers with challenges more numerous and more difficult than those encountered in genomics research.

The structure of a protein molecule is much more complicated than the DNA molecule, which is a linear molecule composed of only four randomly repeating subunits (nucleotides). Proteins, which consist of a chain of up to 22 randomly repeating subunits (amino acids), wind into complicated, intricate shapes, and those shapes are essential to each protein's function. It is known that the sequence of amino acids affects the shape a protein assumes, but it is not clear what the rules are that govern the folding process. Therefore, using the amino acid sequence to predict protein shape and, through this, protein functionality is beyond our current capabilities.

There are thousands of proteins that differ greatly from one another, even within the same individual, but DNA molecules are remarkably similar. In addition, unlike the unvarying genome, an organism's proteome is so dynamic that an almost infinite variety of protein combinations exists. The genome is constant irrespective of cell type and age, but the proteome varies from one cell type to the next, from one year to the next, and even from moment to moment. The cellular proteome changes in response to other cells in the body and external environmental conditions. A single gene can code for different versions of a protein, each with a different function.

When the Human Genome Project began, the first task researchers took on was developing the necessary tools for completing the project's goals and objectives. Proteomics researchers currently find themselves in a similar position—needing to develop more tools before they can address many proteomics objectives, such as

- cataloguing all of the proteins produced by different cell types.
- determining how age, environmental conditions and disease affect the proteins a cell produces.
- discovering the functions of these proteins.
- charting the progression of a process—such as disease development, the steps in the infection process or the biochemical response of a crop plant to insect feeding—by measuring waxing and waning protein production.
- discovering how a protein interacts with other proteins within the cell and from outside the cell.

Bioinformatics Technology

Conducting the biological research just described is impossible without computers and the Internet. The common language of computers allows researchers all over the world to contribute and access biological data; the universal language of life enables collaborations among scientists studying any plant, animal or microbe.

The most formidable challenge facing researchers today remains in informatics: how to make sense of the massive amount of data provided by biotechnology's powerful research tools and techniques. The primary problems are how to collect, store and retrieve information; manage data so that access is unhindered by location or compatibility; provide an integrated form of data analysis; and develop methods for visually representing molecular and cellular data.

Bioinformatics technology uses computational tools provided by the information technology revolution, such as statistical software, graphics simulation, algorithms and database management, for consistently organizing, accessing, processing and integrating data from different sources. Bioinformatics consists, in general, of two branches. The first concerns data gathering, storing, accessing and visualization; the second branch focuses more on data integration, analysis and modeling and is often referred to as *computational biology.*

As more and more information is amassed on genes, molecules and cells, and scientists need to integrate findings based on different experimental methods and different organisms, computers will become increasingly indispensable. *Systems biology* is the branch of biology that attempts to use biological data to create predictive models of cell processes, biochemical pathways and, ultimately, whole organisms. Systems biologists develop a series of mathematical models of processes and pathways to elucidate the full complexity of the interactions that occur in biological systems. Only with iterative biosimulations generated by computers will scientists be able to develop a complete picture of the system being studied.

Bioinformatics and systems biology should provide more effective and efficient routes to commercial routes. Over time, biotechnology products will be increasingly focused on systems and pathways, not single molecules or single genes. Bioinformatics technology will be an essential component of every step in product research, development and commercialization.

6.5 Product Development Applications

The rich understanding of biological systems in health and disease that the techniques described is not an end in itself. Companies must turn the information gleaned from basic research, genomics and proteomics into useful products. The tools and techniques of biotechnology are helpful throughout the product discovery and development process.

6.5.1 Product Discovery

A fundamental challenge facing many sectors of the biotechnology industry to improve the rate of product discovery. Some of the discoveries provided by basic research in cell and molecular biology, genomics and proteomics will lead directly to new products.

In addition, knowing only portions of the DNA sequence of certain genes can provide useful products, even without knowing about the gene's function or the protein it encodes. For example, new product discoveries based solely on DNA sequence data acquired through structural genomics include

- diagnostic tests for plant, animal and human diseases.
- tests to identify the presence of genetically modified food products.
- antisense molecules to block gene expression.
- tests to identify genetic susceptibilities to certain diseases.
- diagnostics for microbial contaminants in food products or donated blood.
- tests for drug-resistant mutants of HIV and other pathogens.
- gene-based therapeutics, such as DNA vaccines or gene therapies.

The information accumulating from studies of structural and functional genomics, proteomics and basic biology bolsters new product discovery by improving understanding of the basic biology of the processes t to control or change. Understanding the process leads to new and better products, and sometimes provides new uses for old products. For example, understanding the molecular basis of high blood cholesterol and diabetes, as well as the molecular mechanism of action of the statins, leads many researchers to believe that the statins, which were designed to reduce cholesterol levels, might also help diabetics.

The benefits of understanding to new product discovery apply to all industrial sectors that use biotechnology: pharmaceuticals, agriculture, food processing, forestry and industrial manufacturing.

6.5.2 Product Development

Genomics, proteomics, microarray technology, cell culture, monoclonal antibody technology and protein engineering are just a few of the biotechnologies that are being brought to bear at various stages of product development. Understanding the molecular basis of a process will provide measures of product efficacy that can be assayed in cells, which can save companies time and money. For example, agricultural biotechnology companies developing insect-resistant plants can measure the amount of protective protein that a plant cell produces and avoid having to raise plants to maturity. Pharmaceutical companies can use cell culture and microarray technology to test the safety and efficacy of drugs and observe adverse side effects early in the drug development process.

In addition, by genetically modifying animals to produce the therapeutic protein target or developing transgenic animal models of human diseases that closely resemble the pathophysiology of human diseases, the results from clinical trials should be more applicable to human systems. As a result, companies can identify safe and effective product candidates much earlier in the product development process.

The biotechnologies can also improve profitability by shortening the product development process because a single technology might be used at many steps in the process. For example, a small piece of DNA that the research lab uses to locate a gene in the genome of a plant pathogen may eventually become a component of a diagnostic test for that pathogen. A monoclonal antibody developed to identify therapeutic leads might be used to recover and purify that therapeutic compound during scale-up.

6.5.3 Health-Care Applications

Biotechnology tools and techniques open new research avenues for discovering how healthy bodies work and what goes wrong when problems arise. Knowing the molecular basis of health and disease leads to improved and novel methods for treating and preventing diseases. In human health care, biotechnology products include quicker and more accurate diagnostic tests, therapies with fewer side effects because they are based on the body's self-healing capabilities, and new and safer vaccines.

Diagnostics

Many diseases and medical conditions can now be detected more quickly and with greater accuracy because of the sensitivity of new, biotechnology-based diagnostic tools. A familiar example of biotechnology's benefits is the new generation of home pregnancy tests that provide more accurate results much earlier than previous tests. Tests for strep throat and many other infectious diseases provide results in minutes, enabling treatment to begin immediately in contrast to the two- or three-day delay of previous tests.

Biotechnology has also decreased the costs of diagnostics. A new blood test, developed through biotechnology, measures the amount of low-density lipoprotein (LDL), or "bad" cholesterol, in blood. Conventional methods require separate and expensive tests for total cholesterol, triglycerides and high-density lipoprotein cholesterol. Also, a patient must fast 12 hours before the test. The new biotech test measures LDL in one test, and fasting is not necessary. Biotechnology-based tests are now used to diagnose certain cancers, such as prostate and ovarian cancer, by taking a blood sample, eliminating the need for invasive and costly surgery.

In addition to diagnostics that are cheaper, more accurate and quicker than previous tests, biotechnology is allowing diagnoses of diseases earlier in the disease process, which greatly improves a patient's prognosis. Most tests detect diseases once the disease process is far enough along to provide measurable indicators. Proteomics researchers are discovering molecular markers that indicate incipient diseases before visible cell changes or disease symptoms appear. Soon physicians will have access to tests for detecting these biomarkers before the disease begins.

The wealth of genomics information made available by the Human Genome Project will greatly assist doctors in early diagnosis of hereditary diseases, such as type I diabetes, cystic fibrosis, early-onset Alzheimer's and Parkinson's disease, that previously were detectable only after clinical symptoms appeared. Genetic tests will also identify patients with a propensity to diseases, such as various cancers, osteoporosis, emphysema, type II diabetes and asthma, giving patients an opportunity to prevent the disease by avoiding the triggers, such as diet, smoking and other environmental factors.

Biotechnology-based diagnostic tests are not only altering disease diagnosis but also improving the way health care is provided. Many tests are portable, so physicians conduct the tests, interpret results and decide on treatment literally at the patient's bedside. In addition, because many of these diagnostic tests are based on color changes similar to a home pregnancy test, the results can be interpreted without technically trained personnel, expensive lab equipment or costly facilities, making them more available to poorer communities and people in developing countries.

The human health benefits of biotechnology detection methodologies go beyond disease diagnosis. For example, biotechnology detection tests screen donated blood for the pathogens that cause AIDS and hepatitis. Physicians will someday be able to immediately profile the infection being treated and, based on the results, choose the most effective antibiotics.

Therapeutics

Biotechnology will provide improved versions of today's therapeutic regimes as well as treatments that would not be possible without these new techniques. The therapies discussed below share a common foundation. All are derived from biological substances and processes designed by nature. Some use the human body's own tools for fighting infections and correcting problems. Others are natural products of plants and animals. The large-scale manufacturing processes for producing therapeutic biological substances also rely on nature's molecular production mechanisms.

Here are just a few examples of the types of therapeutic advances biotechnology now makes feasible.

Using Natural Products as Therapeutics

Plant cell culture, recombinant DNA technology and cellular cloning, now providenew ways to tap into natural diversity.

The ocean presents a particularly rich habitat for potential new medicines. Marine biotechnologists have discovered organisms containing compounds that could heal wounds, destroy tumors, prevent inflammation, relieve pain and kill microorganisms. Shells from marine crustaceans, such as shrimp and crabs, are made of chitin, a carbohydrate that is proving to be an effective drug-delivery vehicle.

Using Biopolymers as Medical Devices

Biological molecules can serve as useful medical devices or provide novel methods for drug delivery. Because they are more compatible with human tissue, they are superior to most man-made medical devices or delivery mechanisms.

For example, hyaluronate, a carbohydrate produced by a number of organisms, is an elastic, water-soluble biomolecule that is being used to prevent postsurgical scarring in cataract surgery, alleviate pain and improve joint mobility in patients with osteoarthritis and inhibit adherence of platelets and cells to medical devices, such as stents and catheters. A gel made of a polymer found in the matrix connecting cells promotes healing in burn victims. Gauze-like mats made of long threads of fibrinogen, the protein that triggers blood clotting, can be used to stop bleeding in emergency situations. Adhesive proteins from living organisms are replacing sutures and staples for closing wounds. They set quickly, produce strong bonds and are absorbed.

Replacing Missing Proteins

Some diseases are caused when defective genes don't produce the proteins (or enough proteins) the body requires. Recombinant DNA and cell culture is now used to produce the missing proteins. Replacement protein therapies include

- factor VIII — a protein involved in the blood-clotting process, lacked by some hemophiliacs.
- insulin — a protein hormone that regulates blood glucose levels. Diabetes results from an inadequate supply of insulin.

Using Genes to Treat Diseases

Gene therapy is a promising technology that uses genes, or related molecules such as RNA, to treat diseases. For example, rather than giving daily injections of missing proteins, physicians could supply the patient's body with an accurate instruction manual — a nondefective gene — correcting the genetic defect so the body itself makes the proteins. Other genetic diseases could be treated by using small pieces of RNA to block mutated genes.

Only certain genetic diseases are amenable to correction via *replacement gene therapy.* These are diseases caused by the lack of a protein, such as hemophilia and severe combined immunodeficiency disease (SCID).

Medical researchers have also discovered that gene therapy can treat diseases other than hereditary genetic disorders. They have used briefly introduced genes, or *transient gene therapy,* as therapeutics for a variety of cancers, autoimmune disease, chronic heart failure, disorders of the nervous system and AIDS.

Cell Transplants

Scientists are investigating how to use cell culture to increase the number of patients who might benefit from one organ donor. Liver cells grown in culture and implanted into patients kept them alive until a liver became available. To treat type 1 diabetes, researchers implanted insulin-producing cells from organ donors into the subjects' livers. Eighty percent of the patients required no insulin injections one year after receiving pancreatic cells; after two years, 71 percent had no need for insulin injections. In another study, skeletal muscle cells from the subject repaired damage to cardiac muscle caused by a heart attack.

As is true of patients receiving whole-organ transplant, expensive drugs for suppressing the immune response must be given if the transplanted cells are from someone other than the patient. Researchers are devising ways to keep the immune system from attacking the new cells. Cell encapsulation allows cells to secrete hormones or provide a specific metabolic function without being recognized by the immune system.

Other conditions that could potentially be treated with cell transplants are cirrhosis, epilepsy and Parkinson's disease.

Stimulating the Immune System

Researchers can also increase the number of a specific type of cell, with a highly specific function, from the *cellular branch* of the immune system. Under certain conditions, the immune system may not produce enough of the cell type a patient needs. Cell culture and natural growth factors that stimulate cell division allow researchers to shift the cellular balance toward the needed cell type.

Suppressing the Immune System

Inflammation, another potentially destructive immune system response, can cause diseases characterized by chronic inflammation, such as ulcerative colitis. Two cytokines, interleukin-1 and tumor necrosis factor, stimulate the inflammatory response, so a number of biotechnology companies are investigating therapeutic compounds that block the actions or decrease production of these cytokines.

Xenotransplantation

Organ transplantation provides an especially effective, cost-efficient treatment for severe, life-threatening diseases of the heart, kidney and other organs. According to the United Network of Organ Sharing (UNOS), in the United States more than 60,000 people are on organ recipient lists, while another 100,000 need organs, but are not on lists.

Organs and cells from other species may be promising sources of donor organs and therapeutic cells.

Regenerative Medicine

Biotechnology permits the use of the human body's natural capacity to repair and maintain itself. The body's ability to self-repair and maintain includes many different proteins and various populations of stem cells that have the capacity to cure diseases, repair injuries and reverse age-related wear and tear.

Tissue Engineering

Tissue engineering combines advances in cell biology and materials science, allowing the creation semi-synthetic tissues and organs in the lab. These tissues consist of biocompatible scaffolding material, which eventually degrades and is absorbed, plus living cells grown using cell culture techniques. Ultimately the goal is to create whole organs consisting of different tissue types to replace diseased or injured organs.

The most basic forms of tissue engineering use natural biological materials, such as collagen, for scaffolding. For example, two-layer skin is made by infiltrating a collagen gel with connective tissue cells, then creating the outer skin with a layer of tougher protective cells. In other methods, rigid scaffolding, made of a synthetic polymer, is shaped and then placed in the body where new tissue is needed. Other synthetic polymers, made from natural compounds, create flexible scaffolding more appropriate for soft-tissue structures, like blood vessels and bladders. When the scaffolding is placed in the body, adjacent cells invade it. At other times, the biodegradable implant is supplemented with cells grown in the laboratory prior to implantation.

Simple tissues, such as skin and cartilage, were the first to be engineered successfully. Recently, however, physicians have achieved remarkable results with a biohybrid kidney that maintains patients with acute renal failure until the injured kidney repairs itself. A group of patients with only a 10 to 20 percent probability of survival regained normal kidney function and left the hospital in good health because the hybrid kidney prevented the events that typically follow kidney failure: infection, sepsis and multi-organ failure. The hybrid kidney is made of hollow tubes seeded with kidney stem cells that proliferate until they line the tube's inner wall. These cells develop into the type of kidney cell that releases hormones and is involved with filtration and transportation. In addition to carrying out these expected metabolic functions, the cells in the hybrid kidney also responded to signals produced by the patient's other organs and tissues.

Natural Regenerative Proteins

The human body produces an array of small proteins known as growth factors that promote cell growth, stimulate cell division and, in some cases, guide cell differentiation. These proteins can be used to help wounds heal, regenerate injured tissue and advance the development of tissue engineering described in earlier sections. As proteins, they are prime candidates for large-scale production by transgenic organisms, which would enable their use as therapeutic agents.

Some of the most common growth factors are epidermal growth factor, which stimulates skin cell division and could be used to encourage wound healing; erythropoietin, which stimulates the formation of red blood cells and was one of the first biotechnology products; fibroblast growth factor, which stimulates cell growth and has been effective in healing burns, ulcers and bone and growing new blood vessels in patients with blocked coronary arteries; transforming growth factor-beta, which helps fetal cells differentiate into different tissue types and triggers the formation of new tissue in adults; and nerve growth factors, which encourage nerve cells to grow, repair damage and could be used in patients with head and spinal cord injuries or degenerative diseases such as Alzheimer's.

Stem Cells

Stem cell research represents the cutting edge of science — a biotechnology method that uses cell culture techniques to grow and maintain stable cell lines. Stem cell therapies could revolutionize approaches for treating many of our most deadly and debilitating diseases and afflictions such as diabetes, Parkinson's, Alzheimer's, stroke and spinal cord injuries. Development of the remarkable biohybrid kidney described above depended on a supply of kidney stem cells.

Most cells in the human body are differentiated — meaning they have a specific shape, size and function. Some cells exist only to carry oxygen through the bloodstream, others to transmit nerve signals to the brain and so forth. Stem cells are cells that have not yet differentiated. Different types of stems cells display varying degrees of plasticity regarding their potential fate.

In adults, some tissues maintain a population of stem cells to replenish cells that have died or been injured; other tissues have no resident stem cell populations. When an *adult stem cell* receives a cue to differentiate, it first divides in two: One daughter cell differentiates, the other remains undifferentiated, ensuring a continual supply of stem cells. Bone marrow contains stem cells that can differentiate into any of the cell types found in blood, such as red blood cells, T-cells and lymphocytes, and bone. Liver stem cells can become any of the specialized cells of the liver — bile-secreting cells, storage cells or cells that line the bile duct. But stem cells in the liver do not differentiate into T-cells, and bone marrow stem cells do not become liver cells.

In 1998, researchers reported that they had established human *embryonic stem cell* lines. This breakthrough opened up many avenues for treating diseases and healing injured tissue because embryonic stem cells can become any kind of cell in the body. Embryonic stem cells are derived from a blastocyst, which is the ball of about 150 undifferentiated cells from which an embryo develops. In addition to their total developmental plasticity, embryonic stem cells can produce more of themselves without limit.

By starting with undifferentiated adult and embryonic stem cells, scientists may be able to grow cells to replace tissue damaged from heart disease, spinal cord injuries and burns, and to treat diseases such as Parkinson's, diabetes and Alzheimer's by replacing malfunctioning cells with newly differentiated healthy cells. This process of culturing a line of genetically identical cells to replace defective cells in the body is sometimes referred to as therapeutic cloning.

Cell Nuclear Replacement

The potential value of stem cell therapy and tissue engineering can best be realized if the therapeutic stem cells and the tissues derived from them are genetically identical to the patient receiving them. Therefore, unless the patient is the source of the stem cells, the stem cells need to be "customized" by replacing the stem cell's genetic material with the patient's before cueing the stem cells to differentiate into a specific cell type. To date, this genetic material replacement and reprogramming can be done effectively only with embryonic stem cells.

More information about cell nuclear replacement can be found in "Ethics" and "Biotechnology Tools in Research and Product Development."

Vaccines

Vaccines help the body recognize and fight infectious diseases. Conventional vaccines use weakened or killed forms of a virus or bacteria to stimulate the immune system to create the antibodies that will provide resistance to the disease. Usually only one or a few proteins on the surface of the bacteria or virus, called antigens, trigger the production of antibodies. Biotechnology is helping improve existing vaccines and create new vaccines against infectious agents, such as the viruses that cause cervical cancer and genital herpes.

Biotechnology Vaccine Production

Most of the new vaccines consist only of the antigen, not the actual microbe. The vaccine is made by inserting the gene that produces the antigen into a manufacturing cell, such as yeast. During the manufacturing process, which is similar to brewing beer, each yeast cell makes a perfect copy of itself and the antigen gene. The antigen is later purified. By isolating antigens and producing them in the laboratory, it is possible to make vaccines that cannot transmit the virus or bacterium itself. This method also increases the amount of vaccine that can be manufactured because, unlike traditional vaccine production, biotechnology vaccines can be made without using live animals.

Using these techniques of biotechnology, scientists have developed antigen-only vaccines against life-threatening diseases such as hepatitis B and meningitis.

Recently scientist have discovered that injecting small pieces of DNA from microbes is sufficient for triggering antibody production. Such *DNA vaccines* could provide immunization against microbes for which there are currently no vaccines. DNA vaccines against HIV, malaria and the influenza virus are currently in clinical trials.

Biotechnology is also broadening the vaccine concept beyond protection against infectious organisms. Various researchers are developing vaccines against diseases such as diabetes, chronic inflammatory disease, Alzheimer's disease and cancers.

Vaccine Delivery Systems

Whether the vaccine is a live virus, coat protein or a piece of DNA, vaccine production requires elaborate and costly facilities and procedures. And then there's the issue of painful injections. Industrial and academic researchers are using biotechnology to circumvent both of these problems with edible vaccines manufactured by plants and animals.

Genetically modified goats have produced a possible malaria vaccine in their milk. University researchers have obtained positive results using human volunteers who consumed hepatitis vaccines in bananas, and *E. coli* and cholera vaccines in potatoes. In addition, because these vaccines are genetically incorporated into food plants and need no refrigeration, sterilization equipment or needles, they may prove useful in developing countries.

Researchers are also developing skin patch vaccines for tetanus, anthrax and *E. coli.*

Genomics and Proteomics

Revolutionary advances in research, product development and disease management are being driven by the interrelated and rapidly evolving scientific disciplines of genomics and proteomics. These areas of study are elucidating the precise mechanisms that drive and direct biological processes; they're also providing detailed information about the molecular basis of diseases.

Genomics and proteomics will allow expansion of current biotechnology-based approaches to health care: therapeutic uses of endogenous proteins and antibodies, discovery of new therapeutic compounds in plants and other organisms, microbe-free vaccines, quick and accurate diagnostics, regenerative medicine and gene therapy to treat certain diseases.

More importantly, however, these advances will bring about radically new approaches to health care. The practice of medicine will be fundamentally changed, becoming more comprehensive and integrated, highly individualized and more preventive rather than simply therapeutic. The expanded knowledge base provided by genomics and proteomics will serve as the foundation for

- predictive tests of impending diseases that can be prevented with targeted interventions.
- fundamental changes in the way drugs are discovered, tested and developed.
- therapies that are tailored to the specific genetic makeup of the patient.
- therapies that address and sometimes correct the biochemical causes of a disease rather than only alleviating the symptoms.

6.5.4 Agricultural Production Applications

The demand for resources provided by plants and animals will increase as the world's population grows. The global population, which numbered approximately 1.6 billion in 1900, has surged to 6 billion and is expected to reach 10 billion by 2030. The United Nations Food and Agriculture Organization estimates world food production will have to double on existing farmland if it is to keep pace with the anticipated population growth.

Biotechnology can help meet the ever-increasing need by increasing yields, decreasing crop inputs such as water and fertilizer, and providing pest control methods that are more compatible with the environment.

Crop Biotechnology

Today virtually every crop plant grown commercially for food or fiber is a product of crossbreeding, hybridization or both. Unfortunately, these processes are often costly, time consuming, inefficient and subject to significant practical limitations. For example, producing corn with higher yields or natural resistance to certain insects takes dozens of generations of traditional crossbreeding, if it is possible at all.

The tools of biotechnology allow plant breeders to select single genes that produce desired traits and move them from one plant to another. The process is far more precise and selective than traditional breeding in which thousands of genes of unknown function are moved into our crops.

Biotechnology also removes the technical obstacles to moving genetic traits between plants and other organisms. This opens up a world of genetic traits to benefit food production. For example a bacterium gene that yields a protein toxic to a disease-causing fungus and can be transferred to a plant. The plant then produces the protein and is protected from the disease without the help of externally applied fungicides.

Improving Crop Production

The crop production and protection traits agricultural scientists are incorporating with biotechnology are the same traits they have incorporated through decades of crossbreeding and other genetic modification techniques: increased yields; resistance to diseases caused by bacteria, fungi and viruses; the ability to withstand harsh environmental conditions such as freezes and droughts; and resistance to pests such as insects, weeds and nematodes.

Natural Protection for Plants

Just as biotechnology allows better use of the natural therapeutic compounds our bodies produce, it also provides more opportunities to partner with nature in plant agriculture.

Plants, like animals, have built-in defense systems against insects and diseases, and scientists are searching for environmentally benign chemicals that trigger these natural defense mechanisms so plants can better protect themselves.

Biotechnology will also open up new avenues for working with nature by providing new *biopesticides,* such as microorganisms and fatty acid compounds, that are toxic to targeted crop pests but do not harm humans, animals, fish, birds or beneficial insects. Because biopesticides act in unique ways, they can control pest populations that have developed resistance to conventional pesticides.

A biopesticide farmers (including organic farmers) have used since the 1930s is the microorganism *Bacillus thuringiensis,* or Bt, which occurs naturally in soil. Several of the proteins the Bt bacterium produces are lethal to certain insects. Bt bacteria used as a biopesticidal spray can eliminate target insects without relying on chemically based pesticides.

Using the flexibility provided by biotechnology, the genetic information that makes the Bt bacterium lethal to certain insects (but not to humans, animals or other insects) can be transplanted into plants on which that insect feeds. The plant that once was a food source for the insect now kills it, lessening the need to spray crops with chemical pesticides to control infestations.

Herbicide Tolerance

Good planting conditions for crops will also sustain weeds that can reduce crop productivity as they compete for the same nutrients the desired plant needs. To prevent this, herbicides are sprayed over crops to eliminate the undesirable weeds. Often, herbicides must be applied several times during the growing cycle, at great expense to the farmer and possible harm to the environment.

Using biotechnology, it is possible to make crop plants tolerant of specific herbicides. When the herbicide is sprayed, it will kill the weeds but have no effect on the crop plants. This lets farmers reduce the number of times herbicides have to be applied and reduces the cost of producing crops and damage to the environment.

Resistance to Environmental Stresses

In addition to the biological challenges to plant growth and development just described, crops plants must contend with abiotic stresses nature dispenses regularly: drought, cold, heat and soils that are too acidic or salty to support plant growth. While plant breeders have successfully incorporated genetic resistance to biotic stresses into many crop plants through crossbreeding, their success at creating crops resistant to abiotic stresses has been more limited, largely because few crops have close relatives with genes for resistance to these stresses.

The crossbreeding limitation posed by reproductive compatibility does not impede crop biotechnology; genes found in any organism can be used to improve crop production. As a result, scientists are making great strides in developing crops that can tolerate difficult growing conditions.

For example, researchers have genetically modified tomato and canola plants that tolerate salt levels 300 percent greater than non-genetically modified varieties. Other researchers have identified many genes involved in cold, heat and drought tolerance found naturally in some plants and bacteria. Scientists in Mexico have produced maize and papaya that are tolerant to the high levels of aluminum that significantly impede crop plant productivity in many developing countries.

Increasing Yields

In addition to increasing crop productivity by using built-in protection against diseases, pests, environmental stresses and weeds to minimize losses, scientists use biotechnology to improve crop yields directly. Researchers at Japan's National Institute of Agrobiological Resources added maize photosynthesis genes to rice to increase its efficiency at converting sunlight to plant starch and increased yields by 30 percent. Other scientists are altering plant metabolism by blocking gene action in order to shunt nutrients to certain plant parts. Yields increase as starch accumulates in potato tubers and not leaves, or oil-seed crops, such as canola, allocate most fatty acids to the seeds.

Biotechnology also allows scientists to develop crops that are better at accessing the micronutrients they need. Mexican scientists have genetically modified plants to secrete citric acid, a naturally occurring compound, from their roots. In response to the slight increase in acidity, minerals bound to soil particles, such as calcium, phosphorous and potassium, are released and made available to the plant.

Nitrogen is the critical limiting element for plant growth and, step-by-step, researchers from many scientific disciplines are teasing apart the details of the symbiotic relationship that allows nitrogen-fixing bacteria to capture atmospheric nitrogen and provide it to the plants that harbor them in root nodules.

- Plant geneticists in Hungary and England have identified the plant gene and protein that enable the plant to establish a relationship with nitrogen-fixing bacteria in the surrounding soil.

- Microbial geneticists at the University of Queensland have identified the bacterial gene that stimulates root nodule formation.

- Collaboration among molecular biologists in the European Union, United States and Canada yielded the complete genome sequence of one of the nitrogen-fixing bacteria species.

- Protein chemists have documented the precise structure of the bacterial enzyme that converts atmospheric nitrogen into a form the plant can use.

Crop Biotechnology in Developing Countries

Today, 70 percent of the people on the planet grow what they eat, and, despite the remarkable successes of the Green Revolution in the 1960s, millions of them suffer from hunger and malnutrition. Continuing population growth, urbanization, poverty, inadequate food-distribution systems and high food costs impede universal access to the higher yields provided by technological advances in agriculture. In addition, the crops genetically improved by plant breeders who enabled the Green Revolution were large-volume commodity crops, not crops grown solely by small-scale subsistence farmers.

For many farmers in developing countries, especially those in sub-Saharan Africa, the Green Revolution never materialized because its agricultural practices required upfront investments — irrigation systems, machinery, fuel, chemical fertilizers and pesticides — beyond the financial reach of small-scale farmers.

Today's biological agricultural revolution is knowledge intensive, not capital intensive, because its technological advances are incorporated into the crop seed. As a result, small-scale farmers with limited resources should benefit. In addition, because of the remarkable flexibility provided by crop biotechnology, crop improvement through genetic modification need no longer be restricted to the large-volume commodity crops that provide a return on industrial R&D investments. A beneficial gene that is incorporated into maize or rice can also be provided to crops grown by subsistence farmers in developing countries because the requirement for plant reproductive compatibility can be circumvented.

Realizing biotechnology's extraordinary capacity for improving the health, economies and living conditions of people in developing countries, many universities, research institutions, government agencies and companies in the industrialized world have developed relationships for transferring various biotechnologies to developing countries. The nature of the relationships varies, depending on the needs and resources of the partners involved. For example:

- Cornell University donated transgenic technology for controlling the papaya ring spot virus to research institutions in Brazil, Thailand and Venezuela and provided their scientists with training in transgenic techniques.

- Japan's International Cooperation Agency built tissue culture facilities at an Indonesian research institution so that scientist there could develop disease-free potato materials for planting. The Indonesian researchers are also working with scientists at Michigan State University to develop insect-resistant potatoes and sweet potatoes.

- An Australian agricultural research center in Australia collaborated with Indonesian researchers on studies of nitrogen fixation and development of disease resistant peanuts.

- Seiberdorf Laboratories (Austria) worked with the Kenyan Agricultural Research Institute to transfer technology for cassava mutagenesis and breeding.

- Monsanto has donated virus resistance technologies to Kenya for sweet potatoes, Mexico for potatoes and Southeast Asia for papaya and technology for pro-vitamin A production in oilseed crops to India.

- Pioneer Hi-Bred and the Egyptian Agricultural Genetic Engineering Research Institute (AGERI) collaborated to discover potentially novel strains of Bt in Egypt. Pioneer trained AGERI scientists in methods for characterizing Bt strains and transgenic techniques. Patents are owned by AGERI and licensed to Pioneer.

- Astra-Zeneca trained scientists from Indonesia's Central Research Institute for Food Crops in the use of proprietary technologies for creating insect-resistant maize.

- The Malaysian palm oil research institute has collaborated with Unilever and universities in England, the United States and the Netherlands on research to change the nutritional value of palm oil and find new uses for it, such as lubricants, fuels, a vitamin E precursor, natural polyester and biodegradable plastics.

While technology transfer has been and, no doubt, will continue to be an essential mechanism for sharing the benefits of crop biotechnology, many developing countries are taking the next step: investing resources to build their own capacity for biotechnology research, development and commercialization. The leaders in these countries recognize the potential of crop biotechnology to provide agricultural self-sufficiency, preserve their natural resources, lower food prices for consumers and provide income to their small farmers. Even more important, they understand that biotechnology has the potential to improve existing exports and create new ones, leading to a more diversified economy and increased independence.

But they also know that many of their agricultural problems are unique and can best be solved by local scientists who are familiar with the intricacies of the problems, local traditions, and applicability — or lack of it — of technologies that were developed to solve agricultural problems in industrialized countries. To move their countries forward, they are investing human and financial resources in developing local strength in crop biotechnology. For example, in the past few months:

- The Malacca government in Malaysia formed a unit in the Chief Minister's Office to promote research and development in biotechnology and established the Sarawak Biodiversity Center to ensure sustainable use of genetic resources and to build a strong database for bioresources.

- Taiwan opened an extension of the Hsinchu industrial park devoted exclusively to biotechnology. Companies in the park will have access to $850 million in government research and development funds and $4 billion in state and private venture capital, plus a wide range of support services including marketing and global patent applications.

- Pakistan's Ministry of Science and Technology prepared a biotechnology action plan and funded a three-year program to promote biotechnology research and development.

- Uganda's National Council of Science and Technology established its first commercial agricultural biotechnology lab to produce disease-free coffee and banana plantlets.

- Egypt's government, a longtime supporter of agricultural biotechnology, released a report encouraging farmers to plant genetically modified crops to benefit from reduced pesticide applications, lower production costs, higher yields and increased income.

Environmental and Economic Benefits

Beyond agricultural benefits, products of crop biotechnology offer many environmental and economic benefits. As described above, transgenic crops allowing increase crop yields by providing natural mechanisms of pest control in place of chemical pesticides. These increased yields can occur without clearing additional land, which is especially important in developing countries. In addition, because biotechnology provides pest-specific control, beneficial insects that assist in pest control will not be affected, facilitating the use of integrated pest management. Herbicide-tolerant crops decrease soil erosion by permitting farmers to use conservation tillage.

Because farmers in many countries have grown biotech crops for years, data is now available for assessing the magnitude of the environmental and economic benefits provided by biotechnology. In the past few years, a number of independent researchers have produced reports documenting these benefits.

According to the National Center for Food and Agricultural Policy's 2002 report, in 2001 the eight transgenic crop varieties adopted by U.S. growers increased crop yields by 4 billion pounds, saved growers $1.2 billion by lowering production costs, and reduced pesticide use by 46 million pounds. Four additional transgenic crops had been approved by the 2001 growing season, but growers opted not to plant them. Had they adopted these varieties, their yields would have increased by an additional 1.1 billion pounds and profits by $158 million; and pesticide use would have decreased by another 582,000 pounds.

In its report "Conservation Tillage and Plant Biotechnology," the Conservation Tillage Information Center (CTIC) at Purdue University attributes the recent improvements in tillage reduction to the increased use of the herbicide-tolerant varieties produced through biotechnology. CTIC concludes that the increase in conservation tillage associated with herbicide-tolerant crops decreases soil erosion by 1 billion tons of soil material per year; saves $3.5 billion per year in sedimentations costs and decreases fuel use by 3.9 gallons per acre.

According to the International Service for the Acquisition of Agri-Biotech Applications, a single transgenic crop, Bt cotton, has led to the following environmental and economic benefits for farmers in developing countries:

- From 1999 to 2000 in China, insecticide usage decreased by 67 percent, yields increased by 10 percent, leading to income gains of $500 per hectare.

- Extensive field trials in India from 1998 to 2001 demonstrated a 50 percent reduction in insecticide spraying, 40 percent increase in yields, which equals an increase in income from $75 to $200 per hectare.

Small farmers in South Africa gained through a 25 percent yield increase and decreased number of insecticide sprays from 11 to four, reducing pesticide costs by $45 per acre. The higher cost of Bt seed (up to $15 per hectare for small farmers) resulted in an average economic advantage of $35 per hectare.

Forest Biotechnology

Throughout the world, wood provides fuel, construction materials and paper, and its supplies are dwindling rapidly. Wood products are currently a $400 billion global industry, employing 3 million people. Demand for wood products is expected to increase, even as major economies, such as Europe and Japan, are unable to grow enough trees to meet their current demand. According to the U.N. Food and Agriculture Organization, world demand for wood products in 2010 will be about 1.9 billion cubic meters, almost 20 percent higher than it is now. Science must attempt to meet that demand preventing cutting down of the world's remaining forests.

Increasing Productivity

Biotechnology is used to create disease- and insect-resistant trees and to increase their growth rates. Scientists are also learning how to use biotechnology to improve the efficiency with which trees convert solar energy into plant material and to shunt more of that energy into wood production and less into pollen, flowers or seeds. All of these methods of increasing productivity should decrease the pressure on natural forests.

However, developing trees through the use of biotechnology is a lengthy undertaking because trees take a long time to grow. So, researchers are looking to other methods for increasing productivity. For example, they are using a biotechnology process in a fungus to fight diseases that infect trees and are working on improving the microorganisms that live on tree roots and provide trees with nutrients, much as nitrogen-fixing bacteria increase the nutrients available to soybeans and alfalfa. In addition, biopesticides have also been used extensively to control forest pests, and progress in insect cell culture to boost the number of biocontrol agents available for forest insect control is expected.

Environmental Benefits

Perhaps a more important economic role for biotechnology in this industry will be found in its changing the conversion process of trees to useful products. Extensive research is being conducted to increase a tree's amount of cellulose, the raw material for papermaking, and to decrease the amount of lignin, a tough molecule that must be removed in papermaking.

Traditionally, removing lignin from trees has required harsh chemicals and high energy costs, so changing the cellulose:lignin ratio genetically has important environmental implications, as does increasing the growth rate of tress. Because trees absorb carbon dioxide, any advance that allows to increase tree yields without cutting down forest could have significant positive effects on global warming. Other environmental benefits that biotechnology is providing to the forestry industry include enzymes for

- pretreating and softening wood chips prior to pulping.
- removing pine pitch from pulp to improve the efficiency of paper-making.
- enzymatically bleaching pulp rather than using chlorine.
- de-inking of recycled paper.
- using wood-processing wastes for energy production and as raw materials for manufacturing high-value organic compounds.
- remediating soils contaminated with wood preservatives and coal tar.

Animal Biotechnology

Animals are playing a growing role in the advancement of biotechnology, as well as increasingly benefiting from biotechnology. Combining animals and biotechnology results in advances in four primary areas:

- Improved animal health through biotechnology.
- Advances in human health through biotechnology studies on animals.
- Enhancements to animal products with biotechnology.
- Environmental and conservation efforts of biotechnology.

Using Biotechnology to Improve Animal Health

Biotechnology-based animal health products and services is estimated to be $2.8 billion and expected to grow to $5.1 billion by 2005. At the end of 2001, there were 2,494 different biologics available for use against 197 different animal diseases. The animal health industry invests more than $400 million a year in research and development.

Farm Animals: Livestock and Poultry

Biotechnology provides new tools for improving animal health and increasing livestock and poultry productivity. These improvements come from the enhanced ability to detect, treat and prevent diseases and other problems; from better feed derived from transgenic crops designed to meet the dietary needs of different farm animals; and from improved animal breeding.

The animal health industry has developed many effective treatments that can prevent and treat dangerous diseases that could potentially strike entire livestock herds and poultry flocks. Quick diagnosis and treatment, coupled with strong preventative measures, help lower production costs and improve overall animal well-being. Additionally, healthier farm animals result in safer and foods for consumers.

- Biotechnology allows farmers to quickly diagnose the following infectious diseases through DNA- and antibody-based tests: brucellosis, pseudorabis, scours, foot and mouth disease, bluetongue, avian leucosis, mad cow disease and trichinosis.

- Farmers may soon be able to manage several farm animal diseases through biotechnology-based pharmaceuticals, including food and mouth disease, classical swine fever and bovine spongiform encephalopathy.

- New biological vaccines protect farm animals from a wider range of diseases, including foot and mouth disease, scours, brucellosis, shipping fever, lung infections affecting pigs (pleuropneumonia, pneumonic pasteurellosis, enzootic pneumonia), hemorrhagic septicemia, fowl cholera, Newcastle disease of poultry, rabies, and infections that affect cultivated fish.

- In addition to these existing vaccines, work is being done to develop a vaccine for an African cattle disease called East Coast fever. If successful, this vaccine would be the first against a protozoan parasite and could lead to the development of a malaria vaccine for humans.

- Molecular-based typing of pathogens, such as genetic fingerprinting, allows for the monitoring of the spread of disease within and between herds and can identify the source of an outbreak.

- Genetic analysis of animal pathogens is leading to an improved understanding of the factors that cause disease and how best to control it.

- Crops improved through biotechnology provide nutritionally enhanced feed for farm animals, with the addition of amino acids and hormones, to improve animal size, productivity and growth rates. Through biotechnology, many of these feeds can increase digestibility of low-quality roughage. Scientists are working on new crops to develop feed with edible vaccines for farm animals. In the near future, pigs could be fed transgenic alfalfa that would stimulate immunity to a serious intestinal virus.

- Researchers are developing a vaccine alternative to castration for livestock. Bull calves are castrated to control aggression, and male pigs are castrated to avoid "boar taint," which makes their meat inedible. The new vaccine will render the animals sterile and eliminate the need for surgery, while ensuring the animals grow well.

In addition to diagnostic tests, vaccines and medicines for farm animals, biotechnology plays a growing role in farm animal breeding programs. With genetic mapping techniques, genetically disease-resistant animals can be identified and used for breeding programs, resulting in naturally healthier offspring. Conversely, animals with some of the following genetic weaknesses and defective genes can be identified and removed from breeding programs:

- New DNA tests can identify pigs with the genetic condition porcine stress syndrome, which causes tremors and death to pigs under stressful conditions.

- Inherited weaknesses of cattle can be identified with DNA tests, which are currently being used in national breeding herds in Japan. Tests can identify leukocyte adhesion deficiency, which causes repeated bacterial infections, stunted growth and death within the first year of life. Factor 13 deficiency, which prevents blood from coagulating normally, can also be identified. Other DNA tests can identify a hereditary condition that produces anemia and retarded growth in Japanese black cattle.

Increasing Livestock Productivity

Livestock producers are always interested in improving the productivity of agricultural animals. Their goal is to obtain the same output (milk, eggs, meat, wool) with less input (food), or increased output with the same input. Increasing muscle mass and decreasing fat in cattle and pigs has long been a goal of livestock breeders.

Additional Applications of Animal Agriculture

- Genetic mapping and the development of DNA markers are being used to identify genes in chickens that have developed a resistance to Marek's disease, a virus-induced disease similar to cancer.

- Scientists have discovered a gene in certain sheep that converts food into muscle 30 percent more efficiently.

- Researchers are developing transgenic plants that produce vaccines for hoof-and-mouth disease, swine gastroenteritis and rabbit hemorrhagic disease.

- Recombinant protein vaccines are under development to control coccidiosis in chickens, which seriously impairs their growth.

- DNA cloning technology is being used to research treatments for cryptosporidiosis, a parasitic disease found mostly in calves, but also in children and immunosuppressed individuals, such as those with AIDS.

- Sodium hyaluronate products, used in the treatment of joint disease in horses and other farm animals, decrease the effect of inflammatory enzymes in cartilage. In addition, a patented biofermentation process is now available that allows these therapies to be given intravenously.

- Many animal feed products are enhanced with proteins to boost nutrition and control disease.

- Injectable products are being used to protect cattle from 36 stages of internal and external parasites, including ostertagi, nematodes and trematodes.

Animal Biotechnology to Enhance Human Medical Applications

Animals are often used as models for research as many of the technologies developed for animals can also be transferred to humans. Some of the work being done with animals that will advance human health:

Xenotransplantation

Extensive research has been done to use animals as blood or organ donors for humans in order to address the worldwide human organ shortage for transplants. The primary hurdle in successful xenotransplantation technology is the rapid rejection of foreign organs by the human immune system. Researchers have developed transgenic pigs with organs that may resist rapid rejection by the human immune system. These pigs are produced with an inactive copy of a gene that triggers rapid human rejection.

"Pharm" Animals

Transgenic animals, including cows, goats and sheep, now produce milk that contains therapeutic proteins that may be used to nourish premature infants or to treat emphysema, cystic fibrosis, burns, gastrointestinal infections and immunodeficiency diseases such as AIDS. Some interesting ongoing projects include:

- Transgenic goats that produce milk containing tissue plasminogen activators (TPA), which can dissolve clots in heart attack victims.

- Dutch researchers are working with transgenic rabbits that secrete a potential drug for Pompe's disease in their milk. Pompe's disease is an extremely rare genetic disorder that can result in crippled muscles, breathing problems and sometimes death.

- Scientists are working with transgenic goats that produce an experimental anticancer medication.

- Transgenic cows can now produce the human milk protein lactoferrin, which is an antibacterial protein that can be used to treat immunosupressed patients or be incorporated into infant formula.

Genetic Sequencing Projects

Numerous genetic sequencing projects are being conducted; understanding the human genome better will lead to the development of new ways to treat disease.

Enhancing Animal Products

Biotechnology can make dramatic improvements to animal products that humans consume and use. Improved animal health conditions from vaccines, medicines and diagnostic tests result in safer foods for consumers. However, biotechnology has made great strides in enhancing animal products at a cellular level through transgenic and cloning technology. Studies conducted by the National Academy of Sciences (NAS) have determined that cloned and transgenic animals and their products are safe for human consumption. Some of these enhancements include:

- Researchers can produce transgenic cows, pigs and lamb with reduced fat and increased lean muscle.

- Genetic mapping projects allow farmers to identify highly productive animals for breeding programs.

- Vaccines have found new uses and can now improve egg production in breeding turkeys. The vaccine stimulates the turkey's immune system to overcome the tendency to stop laying eggs.

- Other vaccines can improve the efficiency of feed conversion or modify hormone production to increase growth rates. Some vaccines can stimulate milk production or produce leaner meat.

- Transgenic cows can now produce "designer milks" with increased levels of protein that can improve the diet of children or affect production of cheese and yogurt. Additionally, scientists are now working to remove from milk the proteins that cause lactose intolerance. It is estimated that 90 percent of the Asian population is lactose intolerant.

- Australian scientists have increased wool production by feeding sheep transgenic lupin, a mainstay of sheep's summer diet.

- Scientists are working to develop transgenic shrimp that lacks the protein responsible for 80 percent of shrimp allergies.

Environmental and Conservation Efforts

Environmental Impacts

Livestock producers are challenged with identifying how to dispose of more than 160 million metric tons of manure annually. Animal manure, especially that of swine and poultry, is high in nitrogen and phosphorus, which can contribute to surface and groundwater pollution. Several crops improved with biotechnology may offer animal feed that decreases phosphorus and nitrogen excretion, total manure excretion and offensive odors.

Endangered Species Conservation

Biotechnology is also providing new approaches for saving endangered species. Reproductive and cloning technologies, as well as medicines and vaccines developed for use in livestock and poultry, can also help save endangered mammals and birds.

Borrowing biotechnology techniques used by livestock breeders, veterinarians at the Omaha zoo used hormonal injections, artificial insemination, embryo culture and embryo transfer to produce three Bengal tiger cubs. A Siberian tigress served as the surrogate mother for these embryos.

In September 2001, researchers at the University of Teramo, Italy, created the first viable clone of an endangered species, the European mouflon. The mouflon is one of the smallest wild sheep in the world. Researchers continue to investigate the use of cloning for other endangered species, such as panda bears and the ox-like gaur. Additionally, a few organizations have created genetic databases to store cryogenically frozen samples of DNA, gametes and cell tissues for later use.

Researchers at the San Diego Zoo have been freezing cells from endangered species since 1975 with the simple objective of studying genetic similarities to other species someday. Their objectives became more momentous with the news that Scottish scientists had cloned a sheep from body cells. Although cloning endangered species has many technical hurdles, the news of Dolly does leave open the possibility that nuclei from those frozen cells could be planted into eggs of similar species and implanted in surrogate mothers. In August 1998 a rare ungulate species related to domestic cattle was successfully cloned at a zoo in the United States.

Biotechnology techniques for working with endangered species have not just been limited to cloning. Some researchers are using genetic samples to study the distribution of species and track the interrelations between different groups of animals. These studies may help to prevent excessive interbreeding among small groups of animals.

Endangered plants may also benefit from the flexibility in problem-solving biotechnology provides. Scientists are developing strategies for resurrecting the American chestnut tree, brought to virtual extinction by chestnut blight, and restoring the Cornish elm tree, 90 percent of which have been destroyed by Dutch elm disease, to Great Britain.

One approach to regenerating populations of chestnuts involves using genomics to identify and isolate genes for blight resistance found in the Chinese chestnut, then adding those genes to the chestnut seedlings that continue to sprout from the trunks of dead chestnut trees. The time frame for creating blight-resistant American chestnuts drops from numbers of generations if scientists use plant breeding to less than five years if plant cell culture and recombinant DNA technology are used.

A fungus transmitted to elm trees by a beetle causes Dutch elm disease. Scientists in the U.K are considering a number of biotechnology options for restoring elms: identify viruses that infect the fungus and use them as biocontrol agents; genetically alter the tree with the Bt gene that specifically kills beetles; and genetically alter the tree to produce substances that will kill the fungus.

Aquaculture

Aquaculture is the growth of aquatic organisms in a controlled environment. The increased public demand for seafood, combined with the relatively small supply of aquaculture products provided by U.S. companies, has encouraged scientists and industry to study ways that marine biotechnology can increase the production of marine food products. By using biotechnology techniques, including molecular and recombinant technology, aquaculture scientists study the growth and development of fish and other aquatic organisms to understand the biological basis of traits such as growth rate, disease resistance or resistance to destructive environmental conditions.

Marine biotechnology is used to identify and combine valuable traits in parental fish and shellfish to increase productivity and improve product quality. The traits scientists and companies are investigating for possible incorporation into several marine organisms include increased production of natural fish growth factors and the natural defense compounds marine organisms use to fight microbial infections. Biotechnology is also improving productivity through the development of feed additives, vaccines and other pharmaceutical agents.

6.5.5 Food Biotechnology

Food biotechnology have used biotechnology to manufacture food products for more than 8,000 years. Bread, alcoholic beverages, vinegar, cheese and yogurt, and many other foods owe their existence to enzymes found in various microorganisms. Today's biotechnology will continue to affect the food industry by providing new products, lowering costs and improving the microbial processes on which food producers have long relied.

Many of these impacts will improve the quality, nutritional value and safety of the crop plants and animal products that are the basis of the food industry. In addition, biotechnology offers many ways to improve the processing of those raw materials into final products: natural flavors and colors; new production aids, such as enzymes and emulsifiers; improved starter cultures; more waste treatment options; "greener" manufacturing processes; more options for assessing food safety during the process; and even biodegradable plastic wrap that kills bacteria.

Improving the Raw Materials

The first generation of transgenic crops primarily benefited farmers. Although there are consumer benefits in growing these crops, the benefits are largely invisible to consumers. For example, studies have shown that because insect-resistant corn (Bt corn) sustains relatively little insect damage, fungi and molds cannot infect those plants as easily as non-insect-resistant crops. Therefore, the level of toxins, such as aflatoxin, produced by these pathogens, some of which are fatal to livestock, is much lower in Bt corn than non-Bt corn.

The benefits of the next wave of biotechnology crops will be more obvious to consumers. Some of those benefits will involve improvements in food quality and safety, while others will provide consumers with foods designed specifically to be healthier and more nutritious.

Health and Nutritional Benefits

A variety of healthier cooking oils derived from biotechnology are already on the market. Using biotechnology, plant scientists have decreased the total amount of saturated fatty acids in certain vegetable oils. They have also increased the conversion of linoleic acid to the fatty acid found mainly in fish that is associated with lowering cholesterol levels.

Another nutritional concern related to edible oils is the negative health effects produced when vegetable oils are hydrogenated to increase their heat stability for cooking or to solidify oils used in making margarine. The hydrogenation process results in the formation of trans-fatty acids.

Biotechnology companies have given soybean oil these same properties, not through hydrogenation, but by using biotechnology to increase the amount of the naturally occurring fatty acid, stearic acid.

Animal scientists are also using biotechnology to create healthier meat products, such as beef with lower fat content and pigs with higher meat-to-fat ratio.

Other health and nutritional benefits of crops improved through biotechnology include increased nutritional value of crops, especially those that are food staples in developing countries. Scientists at Nehru University in New Delhi used a gene found in the South American plant amaranth to increase the protein content of potatoes by 30 percent. These transgenic potatoes also contain large amounts of essential amino acids not found in unmodified potatoes. Other examples include golden rice and canola oil, both of which are high in vitamin A. The golden rice developers further improved rice with two other genes that increase the amount and digestibility of iron.

Biotechnology also promises to improve the health benefits of *functional foods.* Functional foods are foods containing significant levels of biologically active components that impart health benefits beyond our basic needs for sufficient calories, essential amino acids, vitamins and minerals. Familiar examples of functional foods include compounds in garlic and onions that lower cholesterol and improve the immune response; antioxidants found in green tea; and the glucosinolates in broccoli and cabbage that stimulate anticancer enzymes.

Biotechnology is used to increase the production of these compounds in functional foods. For example, researchers at Purdue University and the U.S. Department of Agriculture, created a tomato variety that contains three times as much of the antioxidant lycopene as the unmodified variety. Lycopene consumption is associated with a lower risk of prostate and breast cancer and decreased blood levels of "bad cholesterol. Other USDA researchers are using biotechnology to increase the amount of ellagic acid, a cancer protective agent, in strawberries.

Product Quality

Biotechnology is used to change the characteristics of the raw material inputs so that they are more attractive to consumers and more amenable to processing. Biotechnology researchers are increasing the shelf life of fresh fruits and vegetables; improving the crispness of carrots, peppers and celery; creating seedless varieties of grapes and melons; extending the seasonal geographic availability of tomatoes, strawberries and raspberries; improving the flavor of tomatoes, lettuce, peppers, peas and potatoes; and creating caffeine-free coffee and tea.

Much of the work on improving how well crops endure food processing involves changing the ratio of water to starch. Potatoes with higher starch content are healthier because they absorb less oil when they are fried, for example. Another important benefit is that starchier potatoes require less energy to process and therefore cost less to handle. Many tomato processors now use tomatoes derived from a biotechnology technique, somaclonal variant selection. The new tomatoes, used in soup, ketchup and tomato paste, contain 30 percent less water and are processed with greater efficiency. A ½ percent increase in the solid content is worth $35 million to the U.S. processed-tomato industry.

Another food processing sector that will benefit economically from better quality raw materials is the dairy products industry. Scientists in New Zealand have now used biotechnology to increase the amount of the protein casein, which is essential to cheese making, in milk by 13 percent.

Biotechnology also allows the economically viable production of valuable, naturally occurring compounds that cannot be manufactured by other means. For example, commercial-scale production of the natural and highly marketable sweetener known as fructans has long eluded food-processing engineers. Fructans, which are short chains of the sugar molecule fructose, taste like sugar but have no calories. Scientists found a gene that converts 90 percent of the sugar found in beets to fructans. Because 40 percent of the transgenic beet dry weight is fructans, this crop can serve as a manufacturing facility for fructans.

Safety of the Raw Materials

The most significant food-safety issue food producers face is microbial contamination, which can occur at any point from farm to table. Any biotechnology product that decreases microbes found on animal products and crop plants will significantly improve the safety of raw materials entering the food supply. Improved food safety through decreased microbial contamination begins on the farm. Transgenic disease-resistant and insect-resistant crops have less microbial contamination. New biotechnology diagnostics, similar to those described in the chapter on medical applications of biotechnology, detect microbial diseases earlier and more accurately, so farmers can identify and remove diseased plants and animals before others become contaminated.

Biotechnology is improving the safety of raw materials by helping food scientists discover the exact identity of the allergenic protein in foods such as peanuts, soybeans and milk, so they can then remove them. Although 95 percent of food allergies can be traced to a group of eight foods, in most cases it is unknow which of the thousands of proteins in a food triggered the reaction. With biotechnology techniques, great progress has been made in identifying these allergens. More importantly, scientists have succeeded in using biotechnology to block or remove allergenicity genes in peanuts, soybeans and shrimp.

Finally, biotechnology is improving the safety of raw agricultural products by decreasing the amount of natural plant toxins found in foods such as potato and cassava.

Food Processing

Microorganisms have been essential to the food-processing industry for decades. They play a role in the production of the fermented food. They also serve as a rich source of food additives, enzymes and other substances used in food processing.

Improving Food Fermentors

Because of the importance of fermented foods to so many cultures, scientists are conducting a lot of work to improve the microorganisms that carry out food fermentations. The bacterium responsible for many fermented dairy products, such as cheese and yogurt, is susceptible to infection by a virus that causes substantial economic losses to the food industry. Through recombinant technology, researchers have made some strains of this bacterium and other important fermentors resistant to viral infection.

It has been known for years that some bacteria used in food fermentation produce compounds that kill other, contaminating bacteria that cause food poisoning and food spoilage. Using biotechnology enables equipping many microbial fermentors with this self-defense mechanism to decrease microbial contamination of fermented foods.

Food Additives and Processing Aids

Microorganisms have been essential to the food industry not only for their importance as fermentors, but also because they are the source of many of the additives and processing aids used in food processing. Biotechnology advances will enhance their value to the food industry even further.

Food additives are substances used to increase nutritional value, retard spoilage, change consistency and enhance flavor. The compounds food processors use as food additives are substances nature has provided and are usually of plant or microbial origin, such as xanthan gum and guar gum, which are produced by microbes. Many of amino acid supplements, flavors, flavor enhancers and vitamins added to breakfast cereals are produced by microbial fermentation. Through biotechnology, food processors will be able to produce many compounds that could serve as food additives but that now are in scant supply or that are found in microorganisms or plants difficult to maintain in fermentation systems.

Food processors use plant starch as a thickener and fat substitute in low-fat products. Currently, the starch is extracted from plants and modified using chemicals or energy-consuming mechanical processes. Scientists are using biotechnology to change the starch in crop plants so that it no longer requires special handling before it can be used.

Enzymes produced by microbial fermentation play essential roles as processing aids in the food industry. The first commercial food product produced by biotechnology was an enzyme used in cheese making. Prior to biotech techniques, this enzyme had to be extracted from the stomach of calves, lambs and baby goats, but it is now produced by microorganisms that were given the gene for this enzyme.

The production of high-fructose corn syrup from cornstarch requires three enzymes, and those same enzymes are important in making baked goods and beer. Other enzymes are essential to the production of fruit juices, candies with soft centers, and cheeses. The food industry uses more than

55 different enzyme products in food processing. This number will increase as discovery progress on how to capitalize on the extraordinary diversity of the microbial world and obtain new enzymes that will prove important in food processing.

Food Safety Testing

In addition to the many ways biotechnology enhances the safety of the food supply, biotechnology provides many tools to detect microorganisms and the toxins they produce. Monoclonal antibody tests, biosensors, polymerase chain reaction (PCR) methods and DNA probes are being developed that will be used to determine the presence of harmful bacteria that cause food poisoning and food spoilage, such as *Listeria* and *Clostridium botulinum.*

One can now distinguish *E. coli* 0157:H7, the strain of *E. coli* responsible for several deaths in recent years, from the many other harmless *E. coli* strains. These tests are portable, quicker and more sensitive to low levels of microbial contamination than previous tests because of the increased specificity of molecular technique. For example, the new diagnostic tests for *Salmonella* yield results in 36 hours, compared with the three or four days the older detection methods required.

Biotechnology-based diagnostics have also been developed that enables detection of toxins, such as aflatoxin, produced by fungi and molds that grow on crops, and to determine whether food products have inadvertently been contaminated with peanuts, a potent allergen.

6.5.6 Industrial and Environmental Applications

This third wave of biotechnology is already successfully competing with traditional manufacturing processes and has shown promise for achieving industrial sustainability.

To industry, sustainable development means continuous innovation, improvement and use of "clean" technologies to make fundamental changes in pollution levels and resource consumption. An industrially sustainable process should, in principle, be characterized by

- reduction or elimination of waste.
- low consumption of energy and nonrenewable raw materials (and high use of carbohydrate feedstocks, such as sugars and starch).

Living systems manage their chemistry more efficiently than man-made chemical plants, and the wastes that are generated are recyclable or biodegradable. Biocatalysts, and particularly enzyme-based processes, operate at lower temperatures and produce less toxic waste, fewer byproducts and less emissions than conventional chemical processes. They may also use less purified raw materials (selectivity). Use of biotechnology can also reduce energy required for industrial processes. Finally, just as biotechnology is provides new tools for diagnosing health problems and detecting harmful contaminants in food, it is yielding new methods of monitoring environmental conditions and detecting pollutants.

Biotechnology in industry employs the techniques of modern molecular biology to reduce the environmental impact of manufacturing. Industrial biotechnology also works to make manufacturing processes more efficient for industries such as textiles, paper and pulp, and specialty chemicals. Some observers predict biotechnology will transform the industrial manufacturing sector in much the same way that it has changed the pharmaceutical, agricultural and food sectors. Industrial biotechnology will be a key to achieving industrial and environmental sustainability.

Industrial Sustainability

According to the Organization for Economic Cooperation and Development (OECD), industrial sustainability is the continuous innovation, improvement and use of clean technology to reduce pollution levels and consumption of resources. Modern biotechnology provides avenues for achieving these goals.

In recent years, policy-makers, corporate executives, private citizens and environmentalists have become more concerned about sustainable development. In response to that concern, many leading industrial companies are doing more than meeting their legal minimums. Many are developing policies and implementation plans for sustainability that include guidelines for environmental health and safety as well as product stewardship.

The key words to achieving sustainability are "clean" and "efficient." Any change in production processes, practices or products that makes production cleaner and more efficient per unit of production or consumption is a move toward sustainability.

In practical terms, industrial sustainability means employing technologies and know-how to lessen material and energy inputs, maximize renewable resources and biodegradable substances as inputs, minimize the generation of pollutants or harmful waste during product manufacture and use, and produce recyclable or biodegradable products.

Material and Energy Inputs

Manufacturing processes have long relied on petroleum, a nonrenewable resource that generates pollution and solid waste, as a source of material and energy. Biotechnology provides ways to produce leaner products and processes by reducing the use of petroleum inputs. Industrial biotechnology instead uses natural sugars as feedstocks.

Through biotechnology, the use of renewable, biomass-based feedstocks will increase. Bio-feedstocks offer two environmental advantages over petroleum-based production: Production will be cleaner, in most cases, and less waste will be generated. When the biomass source is agricultural refuse, our gains double: The world will benefit from all the advantages of bio-feedstocks while reducing wastes generated from another human endeavor — agriculture. A final advantage of using plant biomass as feedstock is that as our crop of feedstock grows, it consumes CO_2 — one of the greenhouse gases.

Today at least 5 billion kilograms of commodity chemicals are produced annually in the United States using plant biomass as the primary feedstock.

Biotechnology will also have an impact on two sources of energy: fossil fuels and new biomass-based fuels. Innovations wrought by biotechnology can help remove the sulfur from fossil fuels, significantly decreasing their polluting power. Using biomass for energy has the same environmental advantages as using biomass feedstocks, so government labs have devoted significant resources to research on recombinant technology and bioprocess engineering to improve the economic feasibility of biomass-derived energy.

Industrial Manufacturing Processes

In addition to working toward sustainability by using biomass-based material and energy inputs, biotechnology offers many options for minimizing the environmental impact of manufacturing processes by decreasing energy use and replacing harsh chemicals with biodegradable molecules produced by living things.

Unlike many chemical reactions that require very high temperatures and pressures, reactions using biological molecules work best under conditions that are compatible with life — that is, temperatures under 100° F, atmospheric pressure and water-based solutions. Therefore, manufacturing processes that use biological molecules can lower the amount of energy needed to drive reactions.

Manufacturing processes that use biodegradable molecules as biocatalysts, solvents or surfactants are also less polluting. Microbial fermentation systems have provided some very important industrial solvents, such as ethanol and acetic acid, for decades. Many surfactants used in chemical manufacturing processes are biological molecules that microorganisms produce naturally, such as emulsan and sophorolipids. Marine biotechnologists have recently discovered a surfactant produced by marine microorganisms that may replace chemical solvents. However, the biological products that offer the greatest potential for decreasing the environmental impact of industrial manufacturing processes are the biocatalysts, which are living organisms or simply their enzymes.

Biocatalysts

Industrial biotechnology companies develop new enzymes, biocatalysts, to be used in manufacturing processes of other industries. Enzymes are proteins produced by all living organisms. In humans, enzymes help digest food, turn the information in DNA into proteins, and perform other complex functions. Enzymes are characterized according to the compounds they act upon. Some of the most common enzymes are proteases, which break down protein; cellulases, which break down cellulose; lipases, which act on fatty acids and oils; and amylases, which break starch down into simple sugars.

Industrial biotechnology companies look for biocatalysts with industrial value in the natural environment; improve the biocatalysts to meet very specific needs, using the techniques described below; and manufacture them in commercial quantities using fermentation systems similar to those that produce human therapeutic proteins or bulk yeast for the brewing and baking industries. In some cases, genetically altered microbes (bacteria, yeast, etc.) carry out the fermentation. In other cases, either naturally occurring microbes or microbes genetically modified with other techniques are the production organism.

Discovering Novel Biocatalysts

Companies involved in industrial biotechnology constantly strive to discover and develop high-value enzymes or other bioactive compounds that will improve current manufacturing processes. Chemical processes, including paper manufacturing, textile processing and specialty chemical synthesis, sometimes require very high or very low temperatures or very acidic or alkaline conditions.

Incorporating biocatalysts into manufacturing processes carried out under extreme conditions requires finding organisms that can survive there. The best place to begin the search for such an organism is in natural environments that mimic the extreme manufacturing conditions, and the best organisms to look for in those environments are microorganisms.

Since the dawn of life, microbes have adapted to every imaginable environment. No matter how harsh the environment, some microbe has found a way to make a living there. Life in unusual habitats makes for unique biocatalysts, and the great majority of that biochemical potential remains untapped. Fewer than 1 percent of the microorganisms in the world have been cultured and characterized. Through bioprospecting, scientists are discovering novel biocatalysts that will function optimally at the relatively extreme levels of acidity, salinity, temperature or pressure found in some industrial manufacturing processes — hence the name *extremophiles.*

Information from genomic studies of microbes is helping researchers capitalize on the wealth of genetic diversity in microbial populations. Researchers use DNA probes to fish, on a molecular level, for genes that express enzymes with specific biocatalytic capabilities. Once snared, such enzymes can be identified and characterized for their ability to function in industrial processes, and if necessary, they can be improved with biotechnology techniques.

Improving Existing Biocatalysts

To improve the productivity-to-cost ratio, scientists are modifying genes to increase enzyme productivity in microorganisms currently used in enzyme production. They also give new manufacturing capabilities to these microbial workhorses by genetically altering them to make enzymes that come from microbes that are too expensive or too finicky to cultivate in the lab.

The biotechnology techniques of protein engineering and directed protein evolution maximize the effectiveness and efficiency of enzymes. They have been used to modify the specificity of enzymes, improve catalytic properties or broaden the conditions under which enzymes can function so that they are more compatible with existing industrial processes.

Renewable Energy

Some business leaders and government officials are beginning to discuss ways to move toward a biobased economy in which agricultural operations will be the energy and natural resource fields of tomorrow.

Federal activities include steps by the White House to get federal agencies to pull together in fostering a new biobased economy. President Clinton issued an executive order in the summer of 1999 to establish a biobased products and biobased fuels initiative. This action was meant to encourage industrial use of plant matter "with specific attention to rural economic interests, energy security and environmental sustainability." The goal of the executive order is to triple the nation's use of biobased products and bioenergy by 2010.

Green Plastics

Biotechnology also offers the prospect of replacing petroleum-derived polymers with biological polymers derived from grain or agricultural biomass. Cotton genetically modified to contain a bacterial gene produces a polyester-like substance that is biodegradable and has the texture of cotton, but is warmer.

For example, Cargill Dow in 2001 opened a biorefinery in Blair, Nebraska, to convert sugars from field corn into polylactic acid (PLA) — a compostable biopolymer that can be used to produce packaging materials, clothing and bedding products. Price and performance are competitive with pretroleum-based plastics and polyesters.

Also in 2001, DuPont, and its development partners Genencor and Tate & Lyle, created the high-performance polymer Sorona from the bioprocessing of corn sugar at a biorefinery in Decatur, Illinois. The Sorona fiber has been used to create clothing.

Industrial scientists have also genetically modified both plants and microbes to produce polyhydroxybutyrate, a feedstock for producing biodegradable plastics. Finally, biotechnology provides the opportunity to produce abundant amounts of natural protein polymers, such as spider silk and adhesives from barnacles, through microbial fermentation.

In place of petroleum-based chemicals to create plastics and polyesters, biotechnology uses sugar from plant material. Almost all the giant chemical companies are building partnerships with biotech companies to develop enzymes that can break down plant sugars.

In summary, no matter what stage of industrial production you select — inputs, manufacturing process or final product — biotechnology provides tools, techniques and know-how to move beyond regulatory compliance to proactive pollution prevention and resource conservation strategies that are the hallmarks of industrial sustainability.

Nanotechnology

Industrial biotech companies are taking genomics and proteomics one step further and exploring how to apply this knowledge gained in the organic world to the inorganic world of carbon and silicon. For example, Genencor International and Dow-Corning have partnered to combine their respective expertise in protein-engineered systems and silicon. Their strategic alliance seeks to apply the biotech business model to a third outlet of creativity where products can be developed for other companies based on specific needs.

Such convergence of biotech and nanotech promises to yield many exciting and diverse materials and products. In the area of photonics lies the potential for developing new micro-optical switches and optical micro-processing platforms. In the field of catalysis, the use of inorganic carbon or silicon substrates embedded with biocatalysts has high commercial potential.

Building Nanostructures

One of the more exciting research-stage nano-biotech applications uses knowledge about protein engineering to "build" pre-engineered nanostructures for specific tasks. For instance, certain genes in aquatic microorganisms code for proteins that govern the construction of inorganic exoskeletons. In theory, it should be possible to elucidate these gene functions and re-engineer them to code for nanostructures that could be commercially important, such as specific silicon chips or micro-transistors.

Researchers at the University of Illinois recently discovered a first-of-its-kind carbon-silicon compound in freshwater diatoms. This discovery promises to open the door to understanding the molecular process of biosilicification, or the ways plants and animals build natural structures. This understanding may lead to applications ranging from low-cost synthesis of advanced biomaterials to new treatments for osteoporosis. NASA and some companies are also looking at bioactive ceramics found to have unanticipated bio-adhesive properties. These properties could provide new ways to purify water since bacterial and viruses adhere to these ceramic fibers.

Protein polymer structures are another area ripe for research and development. Industrial biotech companies have years of experience with genetic platform technologies that can be applied to repeating amino acid sequences. These five to six repeat segments can govern the physical structure of a host of biopolymers.

Nexia has unveiled technology to express spider silk in goats, but in the future it may be possible for scientists to build polymers in the lab that are even stronger and that won't need living expression systems for large-scale production. It is not difficult to imagine completely new, commercially attractive polymers being developed using recombinant DNA technology.

Carbon nanotube technology is another exciting area of research and development in the nanoworld. Their great tensile strength makes nanotubes perfect for use in new high-tech composites, for switching in computers, and for the storage of hydrogen energy for transportation or power-generation applications. Carbon nanotubes can be coated with reaction-specific biocatalysts and other proteins for specialized applications. Biotechnology may hold the key to making carbon nanotubes even more economically attractive.

Looking further into the future, the use of DNA fragments for electronic switching come into play, along with the materials just discussed. The number of possible new nano-bio combinations is large.

It is estimated that by 2015 the market for nanotech products could exceed $1 trillion, and that estimate may not have adequately factored in the nano-biotech interface. Suffice it to say this could be a very lucrative field, as also evidenced by the fact that 53 investment firms are planning to put significant sums of money into this area. Industrial biotechnology is poised to merge its applications with carbon and silicon, a merger that could catapult industrial biotech companies from nanospace into financial hyperspace.

Environmental Biotechnology

Environmental biotechnology is the use of living organisms for a wide variety of applications in hazardous waste treatment and pollution control. For example, a fungus is used to clean up a noxious substance discharged by the paper-making industry. Other naturally occurring microbes that live on toxic waste dumps are degrading wastes, such as polychlorobiphenyls (PCBs), to harmless compounds. Marine biotechnologists are studying ways that estuarine bacteria can detoxify materials such as chemical sea brines that cause environmental problems in many industries.

Environmental biotechnology can more efficiently clean up many hazardous wastes than conventional methods and greatly reduce our dependence for waste cleanup on methods such as incineration or hazardous waste dump sites.

How Does It Work?

Using biotechnology to treat pollution problems is not a new idea. Communities have depended on complex populations of naturally occurring microbes for sewage treatment for over a century. Every living organism — animals, plants, bacteria and so forth — ingests nutrients to live and produces a waste byproduct as a result. Different organisms need different types of nutrients. Certain bacteria thrive on the chemical components of waste products. Some microorganisms, for example, feed on toxic materials such as methylene chloride, a variety of detergents and creosote.

Environmental engineers use bioremediation in two basic ways. They introduce nutrients to stimulate the activity of bacteria already present in the soil at a hazardous waste site, or they add new bacteria to the soil. The bacteria then "eat" the hazardous waste at the site and turn it into harmless byproducts. After the bacteria consume the waste materials, they die off or return to their normal population levels in the environment.

The vast majority of bioremediation applications use naturally occurring microorganisms to identify and filter manufacturing waste before it is introduced into the environment or to clean up existing pollution problems. Some more advanced systems using genetically modified microorganisms are being tested in waste treatment and pollution control to remove difficult-to-degrade materials.

In some cases, the byproducts of the pollution-fighting microorganisms are themselves useful. Methane, for example, can be derived from a form of bacteria that degrades sulfur liquor, a waste product of paper manufacturing.

MTBE

One discovered environmental problem is a prime candidate for a bioremediation solution. The U.S. Environmental Protection Agency (EPA) has announced it intends to ban the use of the gasoline additive methyl tertiary butyl ether (MTBE). MTBE is an ether that easily migrates to public drinking water supplies and causes contamination problems. MTBE contamination has become a significant environmental problem in the northeastern states and in California.

Biotechnology offers a potential solution to this problem. Companies involved in environmental biotechnology are developing biological systems that use naturally occurring microorganisms to degrade and remove MTBE that has already polluted underground drinking water supplies.

Environmental Monitoring

The techniques of biotechnology are providing novel methods for diagnosing environmental problems and assessing normal environmental conditions. Companies have developed methods for detecting harmful organic pollutants in the soil using monoclonal antibodies and the polymerase chain reaction, while scientists in government labs have produced antibody-based biosensors that detect explosives at old munitions sites. Not only are these methods cheaper and faster than the current laboratory methods that require large and expensive instruments, but they are also portable. Rather than gathering soil samples and sending them to a laboratory for analysis, scientists can measure the level of contamination on site and know the results immediately.

The remarkable ability of microbes to break down chemicals is proving useful not only in pollution remediation but also in pollutant detection. A group of scientists at Los Alamos National Laboratory work with bacteria that degrade a class of organic chemicals called phenols. When the bacteria ingest phenolic compounds, the phenols attach to a receptor. The phenol-receptor complex then binds to DNA, activating the genes involved in degrading phenol. The Los Alamos scientists added a reporter gene that, when triggered by a phenol-receptor complex, produces an easily detectable protein, thus indicating the presence of phenolic compounds in the environment.

Industries That Benefit

- **The chemical industry:** using biocatalysts to produce novel compounds, reduce waste byproducts and improve chemical purity.

- **The plastics industry:** to decrease the use of petroleum for plastic production by making "green plastics" from renewable crops such as corn or soybeans.

- **The paper industry:** to improve manufacturing processes, including the use of enzymes to lower toxic byproducts from pulp processes.

- **The textiles industry:** to lessen toxic byproducts of fabric dying and finishing processes. Fabric detergents are becoming more effective with the addition of enzymes to their active ingredients. **The food industry:** for improved baking processes, fermentation-derived preservatives and analysis techniques for food safety.

- **The livestock industry:** adding enzymes to increase nutrient uptake and decrease phosphate byproducts.

6.6 Identified Key Opportunities

Members of the technology roadmap working group identified their top opportunities within their respective focus areas. These opportunities were identified by using the Technoscan as a tool in addition to the working group members' own expert knowledge and experience. Those sub-technologies common to all the focus areas, and generally considered to be of highest priority were found to be; functional genomics (with specific focus on gene expression analysis); high throughput screening (based on substantial bioassay development); bioinformatics (including biological data management and extraction); biosafety; and high throughput genome sequencing. The priority technologies span the various stages of new product and service development, extending from discovery to manufacture, but with more emphasis on discovery.

The opportunities identified by each focus area working group are listed below:

6.6.1 Human Health

- **Vaccines.** Development, manufacture and clinical testing of novel human vaccines against important infectious diseases such as HIV/AIDS, TB, malaria, rotavirus and diarrhea.

- **New Drugs/ Pharmacogenetics.** Pharmacogenetics is the study of how genes affect the way people respond to medicines, including antidepressants, chemotherapy treatments, asthma drugs, and many others.

- **Medical Devices.** Ranging from mass produced consumables to high technology based implantable devices, medical devices cover a broad range of products, services and industries with some common traits: they are often hi-tech, require significant development, are often protectable, require international regulatory approval and usually have international markets.

- **Recombinant Therapeutic Products.** Includes the recombinant production of therapeutics, which could be proteins, metabolites, or other small molecules, and the production of generic medicines. It enables the modification of microorganisms, animals and plants so that they produce medically useful substances, for example human proteins.

- **Diagnostics.** Includes the instruments and reagents used for the screening, diagnosis and monitoring or prognosis of a disease by laboratory methodologies. These products may be used in hospitals and private laboratories, in physician's rooms and other point-of-care sites (out-patient clinics, casualties and intensive care units) as well as in home testing (diabetic glucose monitoring and pregnancy tests).

- **Tissue and Cell Engineering.** Involves a multidisciplinary approach drawing from the disciplines of cell biology, developmental biology, molecular biology and biomimetic engineering to regenerate tissues for replacement therapies

- **Stem Cell Engineering.** Stem cell engineering from early human embryos is creating new opportunities for therapeutic and regenerative medicine.

- **Gene Therapy.** Gene therapy is an approach to treat, cure or prevent disease by changing the expression of genes in specific cells in the human body.

- **Nutraceuticals.** Nutraceuticals are foods that demonstrate physiological benefits and reduce the risk of developing a disease. Included in this category are vitamins, antioxidants, dietary supplements and herbs.

- **Probiotics.** A probiotic is a live microorganism or microbial mixture that is administered to humans to bring about a healthy microbial balance particularly in the gastrointestinal tract, the urinary tract and the vagina.

6.6.2 Plant Improvement and Development of Novel Products in Plants

- **Designer super crops.** Super crops for African food production and food security. e.g. one cereal (maize) and one root crop (cassava or potato) with drought, heat, salt tolerance, tolerance to major insect, viral and fungal pests and improved Vitamin A, iron and protein levels.

- **Pharmaceuticals.** Pharmaceutical production in non-food crop such as tobacco.

- **Bioremediation.** Domestic and industrial bioremediation of pollution with designer plants.

- **New Materials.** New industrial materials such as bio-inks and bio-dye
- **Food Production.** Improved nutrition of major crops
- Industry and agriculture. biodegradable plastics
- **Agriculture and medicine.** Pharmaceutical production in non-crop plants, eg tobacco
- **Forestry.** Pest and disease diagnostics
- **Molecular breeding** for improved crop varieties
- **Animal production** through improved feed nutrition
- **Agriculture.** Pest and disease diagnostics

6.6.3 Animal Health

- **Biological Resource Centers.** Gene banks, including culture collections, are essential for the preservation of genetic material, for breeding programmes and conservation purposes as well as for manufacturing vaccines and pharmaceuticals
- **Drug and Vaccine delivery systems.** DNA technology to develop more efficient drug and vaccine delivery systems to improve specificity, safety and efficacy.
- **Genomics of pathogens.** Sequencing pathogen genomes to understand their biology and to identify new antimicrobials
- **Biopharmaceuticals.** The manufacture of pharmaceuticals as well as recombinant DNA vaccines using recombinant DNA technologies. Pros. recombinant DNA technology provides the opportunity to produce new kinds of pharmaceuticals and vaccines. High cost of development makes this a daunting task for any start-up company. Bioprospecting, bio-informatics, bioconversions, genetic-specific typing of medicines.
- **Residues.** Detection of trace quantities of foreign tissues, contaminants and other dangerous compounds, detrimental to human health, animal health and the environment
- **Genomics.** Genomic data will be an invaluable aid in livestock breeding and improvement programs. e.g. Will enable cattle breeders to asses the genetic fitness of their herds and the frequencies of advantageous genes
- **Vaccines.** Preventative vaccinology and related control measures)
- **Bioinformatics.** To identify potential drug targets and to examine pathogen-host interactions

- **Molecular Breeding.** The development of DNA markers to facilitate breeding programmes for traits such as increased productivity, enhanced reproduction, environmental tolerance and disease resistance. Pro: shorter period to produce new breeds. Con: Development of markers can be costly.

- **Gene Therapy.** The development of gene therapies to treat various genetic disorders. Bioprospecting, Biomaterials, Biosensors, Biocomputing, Bioenergy, Bio-informatics

- **Diagnostic Technologies.** Use of recombinant DNA technologies to produce diagnostic tools for the rapid diagnosis of diseases in humans and animals, e.g. HIV, Hepatitis, Foot and Mouth.

- **Molecular or Recombinant Diagnostics.** The use of recombinant DNA technologies to rapidly diagnose the presence of diseases. The advantages are the rapid identification of pathogens allows for more effective disease containment, whereas the major disadvantage is the high initial cost of development.

- **Transgenic animals.** The use of transgenic animals to produce pharmaceutical and other products or improve production e.g. vaccines contained in cows' milk. Pros: New pharmaceutical and other products can be produced cheaply and easily contributing greatly to the economy. Cons: Technology still in the early stages of development and application

6.6.4 Industry, Mining and Environment

- **Production of Enzymes.** This opportunity description is limited to the production of Industrial enzymes. There is also an opportunity in the production of enzymes for diagnostic use as well as an opportunity for the production of enzymes for use in Research

- **Pharmaceutical Intermediates.** At least 50% of all pharmaceuticals are sold as single enantiomers, and many are complicated organic molecules with structures that mimic naturally occurring compounds. Fortunately Nature has evolved highly specific synthetic routes to such material and a high growth area of biotechnology has become the use of biocatalysis and associated techniques to manufacture pharmaceutical actives and intermediates.

- **Fine Chemicals.** There are over 80,000 fine chemicals traded in the international chemical market. These products are used in a number of end markets, including flavours, fragrances, anti-oxidants, food colourants and stabilizers. Biotechnology offers great potential to the safe and cost effective manufacture of such materials.

- **Novel Chemical Entities.** The discovery or design of new chemical entities (NCEs) has largely been limited to the development of new drugs for application in the health arena. Advances in the key technologies of bioinfomatics, genomics and proteomics have revolutionised biotechnology research in the arena of new chemical entity discovery, and the availability of genomic and protein structural data will continue to drive the discovery of new bioactive chemical entities.

- **Commodity Chemicals from Biomass.** Feedstock chemicals serve as the basic building blocks in the synthesis of other chemicals, ranging from small molecules to plastics and rubber, or as solvents in a variety of industrial processes

- **Biomimetic Materials.** Also known as biomimicry or bionics. Biomimesis is the mimicking of natural biological structures or processes to develop manufactured materials, having better properties or improved industrial processes.

- **Hydrogen Production.** Molecular hydrogen is an efficient fuel used in some branches of industry and also as an energy carrier. Biological hydrogen is possible by two routes: fermentative (anaerobic decomposition of organic matter) and photosynthetic (using algae and photosynthetic bacteria).

- **Beneficial Active Microbes.** Production of effective and shelf-stable biological products These products are targeted towards local and export agricultural, aquaculture and environmental markets. Microorganisms can be used as biological control agents against pests, weeds and plant diseases, as probiotics and biostimulants in aquaculture, as bio-degraders of organic waste and as biological decontamination agents in spoiled environments.

- **Bioleaching of Minerals.** Bioleaching of minerals the use microbial-based processes for the extraction and recovery of metal values from mined ores, ore-concentrates, industrial mineral/metals byproducts or wastes.

- **Food, Beverage and Feed Ingredients.** The incorporation of microbial proteins into food products as nutritional supplements, flavourings or functional food ingredients (e.g. Spirulena, yeast hydrolysates, emulsifiers, whipping agents and gelling agents) and applications for enzymes in the food industry.

- **Biopulping of Cellulose.** Prodcution of pulp and paper. The end uses of dissolving pulp include cellophane and rayon, cellulose esters, cellulose ethers, graft and cross-linked cellulose derivatives. The cellulose acetates are widely used in films, eyeglass fames, and cigarette filters, whereas the carboxymethyl cellulose can find applications as a thickener, detergent, and in cosmetics, amongst other uses

- **Bioproduction of Polymers.** Biopolymers as products are classified as fats, carbohydrates, proteins & nucleic acids. They are generated from renewable sources, and are often biodegradable, and non-toxic to produce. They can be via micro-organisms, plants and animals. They are an alternative to petroleum-based polymers, but can also be used as blends with other plastics to enhance environmental properties. Examples include biopolyesters, starches, cellulose and polyphenols.

- **Energy from Renewable Resources.** Alternative and/or renewable raw materials for the production of commercially important products such as plant biomass

- **Mass Production of Plants/Algae for Food/Fuel.** Algae as well as speciality high value niche market products derived from algae are gaining popularity in the intensively growing neutraceutical market

6.6.5 New Biotechnology Platforms

- **Marine and Aquatic Biotechnology:** There is a growing trend to view the marine and aquatic environments as a source of new products for medicine and the chemical industry as well as a food source. Biotechnology shows potential for application in aquaculture and mariculture, for the development of improved fish either through genetic modification or through marker-assisted selection. Biotechnology may also be able to contribute to the control of fish pests and diseases.

- **New Technology Platforms** (Genomics, proteomics, array-based technologies). Critical developments include high throughput sequencing, DNA microarrays, protein chips and arrays, transcriptomics, proteomics, metabolomics. The next trend is to understand interactions between cellular components, such as protein-protein interactions, as well as understanding the functions of individual molecules.

- **Nanotechnology**. Nanotechnology is defined as the fabrication of materials and devices with atomic or molecular scale precision. Many areas that presently form part of biotechnology will be engulfed by this new discipline, through the development of eg biosensors and nano-scale devices with medical application.

- **Biosensors**. Biosensors are compact analytical devices incorporating a biological or biologically-derived sensing element either integrated within or intimately associated with a physicochemical transducer. They incorporate a biological element such as an enzyme, antibody, nucleic acid, microorganism or cell.

- **Bioinformatics and Bio-IT convergance**. Applications of Information Technology (IT) in the biotechnology world include knowledge management systems involving variable pattern matching, pattern discovery, sequence homology, and algorithms for molecular dynamics. Linked developments include Grid computing, the growth of specialized data markup languages, data visualization (simulation, dynamic modelling, virtual reality), and specialized systems for data security and integrity.

- **Bionics**. Bionics is defined as the coupling of living organisms and electronics. This includes artificial muscles, nerve-muscle connections, cochlear implants, sight implants, electronic noses, artificial joints etc. It also includes living cells which are used as sensors and interface with an electronic connection

- **Growth of new limbs and organs**: Regeneration of limbs and organs. The focus is mainly on specific developments such as production and implantation of insulin producing cells to control diabetes. Other work focuses on artificial/cultured skin, bone and hormone-producing implants

- **Xenotransplantation.** This refers to animal-human transplantation. Several techniques have been tried but none have been entirely successful, though they have demonstrated that the concept is viable.

- **Anti-aging research.** Possible breakthroughs will occur as a result of growth factor and stem cell research.

- **Therapeutic antibodies.** Technology trends include the development of hyper-immunized animal antibodies, phage display technologies, human monoclonals produced in vitro or in cloned animals. Antibodies may be linked to other molecules which can detect or kill diseased cells.

- **Artificial foods:** Artificial foods include sugar replacers, dietary supplements, anti-oxidants, probiotic and prebiotic foods. Edible packaging films are being developed. Nutraceuticals and functional foods have the potential to combat cardiovascular disease, reduce cancer risk, combat AIDS related infections, or generally increase physiological well-being over and above the properties of normal foodstuffs.

- **Flavours and natural food products.** The trend in food technology is towards the development of "natural" foods with less processing which retain their flavour qualities. Technology developments include a better understanding of flavour compounds and their effects, better analytical techniques, and more moderate processing techniques, microencapsulation, phase separation, understanding of flavour binding/release phenomena etc.

- **Intelligent clothing, food packaging etc..** Biosensors can be incorporated into clothing so that clothes will sense who is wearing them, what they are doing, and monitor their physiological state. Sensors can also be incorporated into food packaging, for instance to determine whether milk has gone off.

- **Bioneutralization of warfare etc.** Bacteria have been developed that glow in the presence of explosives, contaminants or pollutants, and can be used to signal the presence of dangerous elements. Biosensors can detect the presence of biological and chemical warfare agents and determine the effectiveness of cleaning up waste sites. Biodetection systems functioning as early warning/alert systems involve the detection of biological particle densities by laser eyes and electronic noses with incorporated alarms.

- **Bioadhesives.** Bioadhesive polymers show potential for use in medicine. These materials have several applications in both medical and, in some instances, environmental sensor development. They are also used for slow release drug delivery through skin patches. Bioadhesives from extremophile organisms are currently being developed to be superior when used in extreme conditions of heat, water, oils and solvents

- **Biopolymers:** Biopolymers are generated from renewable natural sources, are often biodegradable, and not toxic to produce. They can be produced by biological systems (i.e. micro-organisms, plants and animals), or chemically synthesized from biological starting materials (e.g. sugars, starch, natural fats or oils, etc.). Biopolymers are an alternative to petroleum-based polymers (traditional plastics). (Bio)polyesters have properties similar to traditional polyesters. Starch-based polymers are often a blend of starch and other plastics, which allows for enhanced environmental properties. Biopolymers include proteins, carbohydrates and nucleic acids.

- **Biolighting/bioluminescence.** Biolighting/bioluminescence is light produced by a chemical reaction that originates in a biological organism. Bioluminescence is a primarily marine phenomenon. It is the predominant source of light in the deep ocean. On land it is most commonly seen as glowing fungus on wood (called foxfire), or in the few families of luminous insects such as fireflies. Proteins involved include luciferases, phosphoproteins and fluorescent proteins.

- **Solid-State Fermentation (SSF).** Solid-State Fermentation is the cultivation of micro-organisms on moist solid raw materials, such as grains, beans or wheat bran. SSF is mainly applicable to fungal fermentations.

- **Biocontrol.** Biocontrol involves the use of microorganisms (usually fungi or bacteria), or extracts from such organisms, to control pests, diseases and weeds in crops. Bacillus thuringiensis insecticidal toxin is the most widely known and used biocontrol product. The search for new proteins has taken on an added impetus because of the potential to clone the genes into the plants themselves.

Those sub-technologies common to all the focus areas, and generally considered to be of highest priority were found to be; functional genomics (with specific focus on gene expression analysis); high throughput screening (based on substantial bioassay development); bioinformatics (including biological data management and extraction); biosafety; and high throughput genome sequencing.

6.7 Government Support for Biotechnology

Biotechnology has rapidly developed in North America and it could be said that the United States of America (USA) is entering the age of a bio-based economy. This prediction is confirmed by the recent Ernst & Young biotechnology survey (2002)[3] which found that the global biotechnology sector experienced its second best financing year ever and outperformed both high-tech and blue chip sectors. In 2001, the USA had 1457 biotechnology companies, Canada had 416, and Europe 1879. Many countries in the Asia/Pacific are applying biotechnology to the discovery of the active ingredients in traditional medicines and to improve the production of essential foods such as rice, and materials such as rubber. In China, agricultural biotechnology is spreading quickly. It is expected that over 50 per cent of agriculture will be biotechnology crops by 2012.

The biotechnology sector is at the start of what may be painful change in the short term, with continued consolidation paring down the number of companies, but long-term industry potential seems limitless.

According to Ernst & Young research one key aspect there has not been enough happening globally to foster biotech -- regulations governing biotech worldwide are not in harmony. Inconsistent patent protection and governance of therapeutically equivalent biologics are two examples of regulatory issues that have affected global access to biotech medicines. Western companies are reluctant to enter partnerships in India and China for fear of losing intellectual property without compensation. Meanwhile, India and China are seizing the change to make therapeutically equivalent versions of biologics from Western nations.

Biotech in India is forecast to generate US$5 billion in revenue and 1 million jobs over the next five years, while the Chinese government invested $180 million from 1996 to last year to create a biotech industry and is expected to spend three times that amount in the next three years. In Japan, biotech workers will increase from 70,000 today to 1 million by 2010. Revenue in Singapore from biomedical manufacturing is expected to hit $7 billion by 2005.

Government support for biotechnology is illustrated by the increased public sector spending on this technology. In India, the Department of Biotechnology has set up a US$21 million biotechnology venture capital fund, while Singapore aims to become the biopharmaceutical R&D hub of the region and Taiwan is promoting biotechnology as the next major growth sector for their economy.

[3] Ernst and Young (2002). *Beyond Borders: The Global Biotechnology Report*, Ernst & Young, UK.

India Venture Capital

The government of India decided support biotechnology firms in the small and medium segment through the launch of new venture capital funds. The government also offered a tax cut of 150% on biotechnology expenditure for research and development (R&D) by the private sector.

The Department of Biotechnology projected biotechnology product demand in India to expand ten times by the year 2007 to US$ 1.5bn. By 2010, demand is forecast to be worth US$ 4.5bn. Pharmaceutical biotechnology and agricultural biotechnology are expected to contribute between 20% and 30%, if not more, to the entire biotechnology market in five years (2008).

The Economic Times, 15 Apr 2003 reported that Biotechnology firms in India have attracted below US$ 60mn worth of venture capital funds as against a venture capital investment of US$ 474mn attracted by 61 biotechnology firms in the US in 2002's October to December period.

In the 2002-2003 year, venture capital funds flowed to a single biotechnology firm in India. There were no Indian biotechnology firms receiving such funds in the 2001-2002 year.

Three biotechnology firms attracted the attention of venture capitalises in the 2000-2001 year. ICICI Venture (I-Venture) might just make a high-profile withdrawal from the local biotechnology industry as it has been trying to discard its interests holding in Biocon for more than 12 months.

Biotechnology in Canada

With more than 300 companies, Canada has the second largest biotechnology industry in the world. Despite a drop in life science investing that spilled over from the U.S., Canada is positioned for a strong future. Reinvigorated investment from venture capitalists and government, strong research-based universities, and Canadian success stories lay the foundation for continued growth.

Many Canadian biotechs are younger and more dependent on venture capital than their U.S. counterparts. Therefore, the Canadian biotech industry was significantly affected by the reduction in investment funding.

Fortunately, the Canadian government has stepped in to help fill the gap. Recognizing the strong economic potential of biotech clusters, many provincial and regional governments have joined forces with the federal government to start venture funds, incubators, and research centres.

Financing opportunities continue to be one of the biggest challenges faced by Canadian life science companies. Small, research-stage companies, without products or profits are most likely to be affected.

Under cautious market conditions, large companies with existing revenues to fund operations and new drug development might be favoured as safe investments, as they will probably be less affected by an economic recession.

But renewed economic optimism in 2002 is reflected in Deloitte & Touche's quarterly Canadian Venture Capital Confidence Surveys. Life sciences is the preferential area of investment with more than half of venture capitalists in Canada planning to increase funding in genomics and biotech companies.

While the valuation of small companies has declined, mergers & acquisitions and partnership activity will continue to grow. Alliances with large drug manufacturers are expected as large-caps accelerate their drug development efforts to support future growth and small-caps look for alternative financing opportunities.

Canada has hosted significant recent mergers & acquisitions such as the sale of BioChem Pharma to Shire Pharmaceuticals Group for $4 billion to form the Quèbec-based subsidiary Shire BioChem Pharma.

Strong research universities are magnets for Research & Development intensive biotech ventures, and Canada is no exception. In fact, our benchmarking analysis (see Table #1) demonstrates that Canadian life science companies spend more effort on R & D than their Australian and San Diego counterparts, with the top quartile exceeding 57% of operating expenses in R&D. Major biotech clusters are growing where there is significant university and hospital network support, such as Montreal, Toronto, Vancouver and Edmonton.

A recent Canadian trend is the increasing independence of biotech firms. Instead of automatically joining forces with big pharmaceutical companies, many biotechs are venturing into commercialization on their own. For example, Aeterna's spin-off Atrium sells fine chemical ingredients for the nutraceutical, cosmeceutical, and pharmaceutical industries.

Maintaining independence is easier if the target market is not medical organizations. However, the emergence of contract marketing organizations in Canada will allow more biotech companies to out-source the marketing of new drugs or products. As this trend becomes increasingly popular, many biotech companies will need additional support to strategically manage their R&D investments to maintain a steady pipeline and ensure long-term growth.

The number of life science success stories like BioChem Pharma and QLT multiply each year.

Aeterna, Biomira, Biovail, and Stressgen are Canadian biotech companies to watch in the future. The biotech industry has created considerable wealth and attracted major investments. Private companies who raised significant captial include Xenon ($70 million CND) and Caprion ($52 million CDN). With more centure funds specialized in life sciences setting up in Canada and more U.S. funds making Canadion Investments, the industry is looking forward to solid growth.

Biotechnology in Australia

Historically, Australia has excelled at basic research and, with a couple of noticeable exceptions, has not focussed on commercialism. However, as the industry matures, this has been changing.

As illustrated by the figures in Table #2, compared to the United States and Canada, Australia is dominated by smaller companies (both smaller by market capitalization and smaller by number of employees).

The vast majority of Australian biotechnology companies are still in the research phase, with few companies having any income from sales of product - hence the small average revenue figures in the table below.

These companies are predominately located on the eastern seaboard with New South Wales (Sydney), Victoria (Melbourne) and Queensland (Brisbane), home to 71 percent of companies by market capitalization.

Despite the relatively early stage of the science in many companies, Australia does have a high percentage of listed biotech companies. The Deloitte Biotech Index tracks a total of 61 listed companies in the sector, more than a third of whom have a market capitalization of less than $10M.

An analysis of the income shows that the majority derive their income from interest and government grants. Forty percent of the companies analysed for this report have 10 or fewer employees is only 32.

This high percentage of small-cap companies may have been caused by the relatively immature biotechnology venture capital market in Australia in the past, although this, too, is changing.

A recent Deloitte & Touche study of Venture Capital confidence shows that confidence amongst Australian VC's is improving while, simultaneously, confidence in the United States and United Kingdom is reaching its lowest levels in years.

Despite the small size of most Australian companies, three biomedical companies are truly global players: ResMed, Cochlear, and CSL. To prevent skewing of the country's results, these three companies were excluded from the analysis. ResMed, Cochlear, and CSL have secured a significant advantage on the global stage, in part because they are located in a lower cost, highly educated country. ResMed, a company fuelled by an Australian but is now listed on the NYSE and has a corporate head office in San Diego.

In addition, we are currently seeing some of the smaller Australian companies such as SIRTeX Medical Limited and Biotechnology Frontiers (BTF) release products on to the United States and European markets and we expect that with these releases the profile of Australian companies will rise.

Other Australian companies including Novogen (NVGN), Progen (PGLAF), and Prana Biotechnology (PRNAF) already have securities traded on Nasdaq with others such as Genetic Technologies announcing plans to have ADR's traded in the US Market.

Australia has a lot to offer in biotechnology:

- Strong, well-funded basic research
- Strong legal framework for the protection of intellectual property
- Well-educated, culturally diverse work force
- Geographic isolation leading to a diverse range of flora and fauna
- Aggressive state and federal governments interested in attracting investment and support biotechnology
- Excellent value for money (salary cost and premises costs)

Australia is a large country with a small population, a land area of 7,682,300 sq km and a population of approximately 20 million people. The key as we see it is how Australia competes with the rest of the world to retain and attract the best biotechnology research and researchers in Australia.

6.8 Biotechnology: Lessons from Sciences and Technology Parks

6.8.1 Science/Industry relations – the role of Science and Technology parks

Principal lessons:

The common attributes of successful parks tend to be: Strong leadership; visionary planning; deep pockets and patience; good timing; appropriate services; meaningful relationships with universities. Provision of adequate seed capital for start-ups; need for entrepreneurship within the universities and generally; need to intertwine the logics of science, business and public policy; improvements in the interface skills of universities;

Good practices identified

Facilitating the creation of spin-offs around S&T parks (Bio region in Germany) Deep involvement of local and regional governments in supporting S/T parks. (The case of Flanders region, Belgium) Using a mix of policy instruments: the Spanish government is using loans and not only grants to support the creation of scientific parks for universities

6.8.2 Public Funding in Biotechnology: the VIB case

In the US long term public funding of molecular biology research eventually led to the establishment of the biotech industry

Principal lessons:

In Flanders, public support has been necessary on the innovative infrastructure level to create communication and cohesion of the local public and private players. Co-ordinating the various research departments from various universities allows VIB to capitalize on economies of scale and scope. Public support has to be available until the regional processes are self-sustainable.

Good practices identified

A common infrastructure available for all research departments, which would be too costly for individual research departments on their own. The long term funding horizon for basic research provided through *the VIB framework, allows human resources to be sustained, which are critical in biotech.*

AUTOMOTIVE SECTOR

7 TECHNOLOGY DEVELOPMENT TRENDS OF AUTOMOTIVE SECTOR

7.1 Summary

With 8.8 million direct and indirect jobs, both with the automobile makers and the automotive suppliers, the automotive industry accounts for 15% of the world's gross domestic product. The automotive industry continues to be one of the world's most important economic sectors.

Globally, South Africa is increasingly becoming one of the major automotive manufacturing centres of the world, producing high quality products at prices competitive with other automotive manufacturing and assembly centers. Locally, South Africa's automotive industry has earned the distinction of being the third most important contributor to the local GDP, behind Mining and Financial Services.

Significant and dynamic changes are, however, occurring in the automotive industry internationally. Unless Government policymakers and sector stakeholders understand and react appropriately to these changes, South Africa may lose its competitive advantage in this sector.

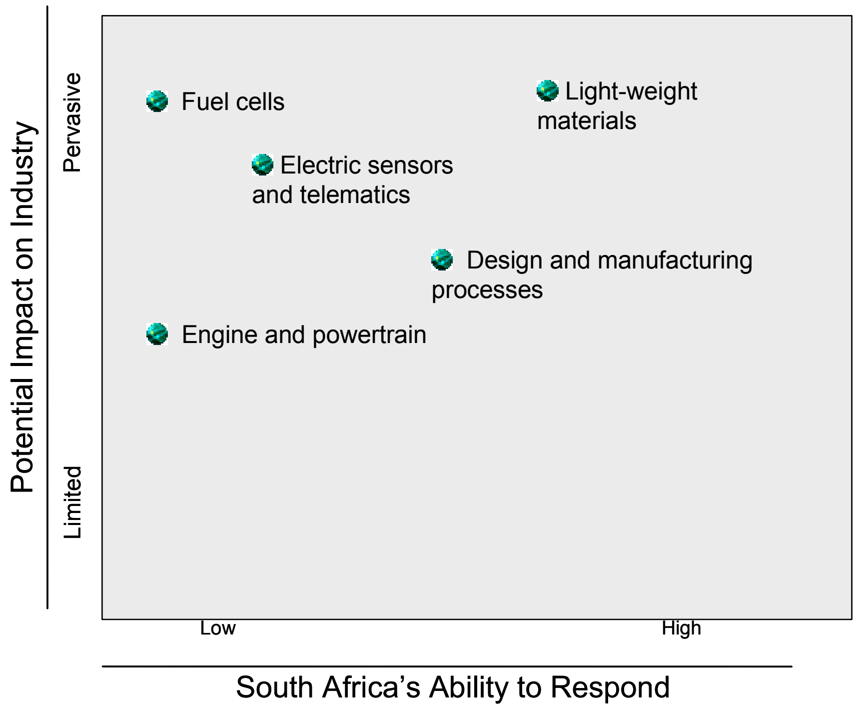
Technology and innovation play a vital role in the automotive industry. This is illustrated by the fact that there are more computers aboard a car today than was aboard the first spaceship. A new car has an estimated 10-15 on-board computers, operating the engine, radio, brakes, transmission, steering systems and other components.

In terms of this study, four technologies were highlighted as being critically important for the continuous development and growth of the automotive sector. These are:

- Development of lightweight materials
- Development of alternate fuels e.g. fuel cell technology
- Sensors, electronics and telematics
- Improved design and manufacturing processes

The following grid graphically positions the South African automotive industry, in terms of these four technologies.

Figure 11: Summary of technologies



The grid positions all four technologies as having a relatively high impact for the South African automotive industry. But in taking cognisance of the current strengths of the local automotive industry, the development of lightweight materials and electronics, sensors and telematics seem to be areas where South Africa can make an impact and possibly, hold a competitive advantage to the rest of the world.

The following gives a brief description of the technology and its importance:

Lightweight materials

In order to reduce fuel consumption, designers in the automotive industry are aiming at reducing the weight of cars as far as possible. By 2020, the weight of a car is expected to reduce by 17%, which translates to some 250 kilograms. Accordingly, weight reduction is one of the main drivers of material selection in the automotive industry.

Sensors, electronics and telematics

The car is increasingly becoming an integral part of new emerging services like access to individual traffic and navigation system, breakdown assistance, automatic emergency calls and traffic control to avoid congestion. This is where sensors, electronics and telematics play an important role. It is estimated that in the near future electronic systems will account for at least 15% of the vehicle value. The use of semiconductors and sensors is expected to grow dramatically.

In conclusion, this study also highlights some of the support mechanisms that other governments have adopted or implemented to boost the competitiveness of their respective automotive sectors. It becomes clear that the automotive sector does not exist in isolation of Government support; rather it uses policies, programmes and support mechanisms as the crutch to propel it to even greater new heights.

7.2 Context of Automotive Sector

7.2.1 Working Definition of Automotive Sector

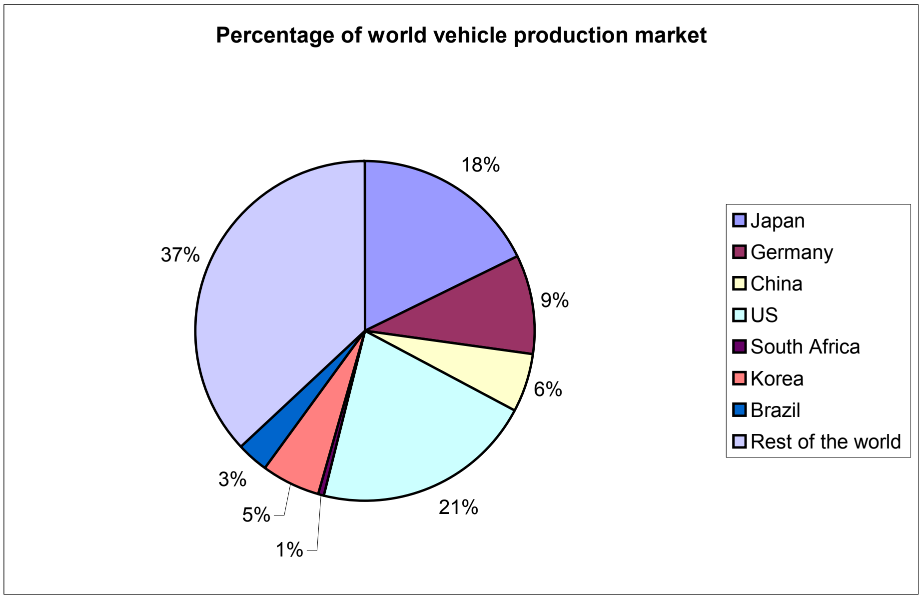
The manufacture of motor vehicles sector includes the manufacture of motor vehicles for the transport of persons and goods, as well as tractors for semi-trailers, and engines for all of these. The vehicle components sector includes the manufacture of parts and accessories for motor vehicles and their engines (including electrical equipment) and the manufacture of vehicle bodies and trailers (UK Standard Industrial Classification of Economic Activities 1992).

7.2.2 Global Automotive Industry

The automotive sector accounts for 15% of the global GDP. With about 8.8 million direct jobs, most of them skilled, it is also one of the largest employment sectors. The value of the sector in 2003 was 645 billion Euros and predicted in 2015 to represent 903 billion Euros. 57 million vehicles were produced in 2003.

The US and Japan dominate in terms of world vehicle production, as the diagram below shows. Over 80% of the world’s vehicle production is accounted for by six major global groups.

Figure 12: Percentage of world vehicle production market



The industry is technologically advanced, both in terms of manufacturing processes and in its products. It is characterised by economies of scale and low unit costs, despite the increasing complexity of the fundamental product. Manufacturers are seeking to differentiate their products through technology and branding.

7.2.3 South African Automotive Industry

The automotive industry can be regarded as being critically important to the economy of South Africa, contributing 5,7% of GDP and 28,5% of total manufacturing GDP. It employs about 290 000 people, directly and even more indirectly.

Relative to its market size of about 360 000 vehicles produced per annum, South Africa has a strong automotive industry. This is in part due to the success of the Motor Industry Development Programme (MIDP), which has promoted the rationalisation of models and growth in exports. It remains, however, primarily a manufacturing and assembly industry, with most of the research, development and design, and to some extent testing, being done abroad (AIDC, 2002).

Although South Africa represents 80% of Africa's vehicle output, it represents only 0,73% of the world production market. Eight of the leading OEM's have manufacturing plants in South Africa namely BMW, GM (Delta Motor Corporation), Daimler Chrysler, Nissan, Ford, Toyota and Volkswagen. They are supported by a large number of first and sector tier component suppliers.

To gain further perspective on the South African automotive industry, the following is a summary of the strengths, weaknesses, opportunities and barriers that currently exist:

7.2.4 Strengths of the Industry

- South Africa produces in excess of 60% of the world's platinum group metals including platinum, rhodium and palladium, which are essential catalysts in the converter
- A high degree of manufacturing flexibility exits. Production lines and cells tend to have a higher degree of labour component than their equivalent overseas plants. This allows more flexibility in manufacture
- Competitive tooling costs. For tooling under a foot (30cm), South African costs are typically half of European costs, for the same quality. This is largely because of the lower labour rates.
- A world beating cost ability on short runs. South African producers are usually set up to make a large number of short runs. This compares to the international norm of being set up for extended runs. Thus local producers can frequently do short runs, i.e. at model run-out or for lower volume vehicles like Volvo and Porsche, at the same quality but at lower cost. Thus a foreign component manufacturer could retain control of their customer at model run-out and source product from South Africa, to the benefit of importer and exporter
- South Africa is a right hand drive country. BMW intends making all its Southern hemisphere, right hand drive, 3 series models in South Africa
- Some unique technologies. Whereas they are few and far between, there are some novel South African developed technologies. For example, a differential lock to give off-road vehicles performance similar to a 4x4 at a fraction of the cost; aluminium welding technology for radiators and; design of components such as air cleaners and air conditioners that must cope with the higher ambient temperatures and dust found in South Africa
- Skills and equipment for forging, casting and working all metals - as demonstrated by decades of experience in supplying high-tech alloy wheels to companies such as BMW
- The support of the SA Government. Government offers a range of supply side measures to encourage investment, development and growth, of which the MIDP (Motor Industry Development Plan) is the most notable

7.2.5 Weaknesses

- Small player in global terms
- Essentially a manufacturing and assembly industry – very little research, development and design work performed in SA
- SA's distance from both its source markets (imports) and sales markets (exports)

- Inefficiencies within the transport sector (road, rail, air)
- Local tooling industry is weak due to fragmentation
- Difficulty in meeting the human resource requirements required by the industry

7.2.6 Opportunities

- Import Rebate System & International Trade Facilitation agreements aid mass export of vehicles
- Tool and machinery export opportunity exists
- Auto technology is sourced primarily from the USA (40 - 50%), the UK (20%) and Germany (20%). The opportunity exists to establish a Centre of Automotive Excellence in South Africa.

7.2.7 Threats/Barriers

- HIV/AIDS - represents an unquantifiable threat at this point
- Local raw material pricing dependent on foreign exchange rates
- Skills base
- Perception of foreign investor friendliness
- Perception by foreign investors of Africa

7.3 Global Technology Trends

Manufacturing is almost entirely reactive to developments in other areas instead of developing on its own line to a considerable extent as well. Particularly, manufacturing is driven by product trends on the one hand, especially new materials, and by demands from globalised markets like flexibility and increasing competition on the other hand.

Both drivers are simultaneously shaping the development and adoption of manufacturing technologies. This is especially true for automotive manufacturing where several new product trends are arising at the moment and which is far ahead in the internationalisation of production.

The automotive industry is a prime sector in driving new technological developments. Because of its high R&D expenses, this industry is determining the direction of research in several areas. Accordingly, many of the technological developments that were outlined in the strand reports as well as discrete transformation processes are driven by the needs of the automotive industry or at least relevant for automotive applications.

7.3.1 Regulatory environment

Energy and power

- Oil resources are of special concern for the automotive industry. The anticipation of future scarcity of conventional fuels is a major driver for the following technological developments:
    - Use of alternative fuels like natural gas and synthetic gas as well as renewable fuel up to electrical power using hybrid concepts
    - Use of fuel cells, which will lead to considerable technical changes throughout the sector and this may also have far-reaching impacts on the related equipment producing industries concerned with the motor and its periphery
    - Reducing vehicle weight is the most cost-effective means to reduce fuel consumption and greenhouse gases from the transportation sector. It is estimated that for every 10 percent reduction in vehicle weight, there is a 6 to 8 percent improvement in fuel economy. This is equivalent to a reduction of about 17 to 20 kg of carbon dioxide (CO2), the main greenhouse gas, per kg of weight reduction over the lifetime of the vehicle. Unless vehicle weights are reduced significantly, it will not be possible to achieve the transportation sector's proportionate reduction of greenhouse gases called for in the Kyoto Protocol on Climate Change without compromising one or more of performance, size, utility, and cost of ownership of cars, trucks, and buses.

Environmental legislation

- Take-back regulations in the EU. Product manufacturers are responsible for the total life-cycle environmental impact of their products, from raw materials extraction and manufacturing to use and disposal. Take-back initiatives place the responsibility of product disposal on the product manufacturer. In the case of end-of-life vehicle management, product take-back creates an incentive for designers to develop products that are reusable, made of recycled materials, and are recyclable.

- Emission standards in the EU. The 2000/2005 regulations allow for EU member states to introduce tax incentives for early introduction of 2005 compliant vehicles; requirement for on-board emission diagnostics systems (OBD) phased in between 2000 and 2005 and requirement for low temperature emission test for gasoline vehicles, effective 2002.

- Tyre pressure monitoring in the US. In response to a series of deadly crashes caused by under inflated tyres, the US Congress recently passed legislation requiring new vehicles to be equipped with some means of monitoring and displaying tyre pressure by 2004. One of the technologies under consideration directly monitors conditions from inside the tyre itself.

- Water regulations and waste disposal in the EU

Structures and materials

Multi-material Processing

The adoption of new materials in cars is a very important driver for the development and implementation of new manufacturing technologies in the automotive industry.

The variety of materials used in automotive design is steadily increasing and there is a clear trend to use specific materials for specific purposes (multi-material design). Another trend mentioned in the interviews and in the environmental reports of car manufacturers (though of minor importance in R&D expenditure) is the use of biodegradable materials to be used for interior parts.

Though the trend to multi-material design or material-mix seems to be universally acknowledged and is expected to be increasing, it is by no means clear which materials will dominate in the future. Instead it is obvious that there is severe competition between different kinds of materials to be used in cars especially in light weight construction.

As each type of material is connected with specific demands on manufacturing processes, it is clear that competition between future materials will be accompanied by competition between manufacturing processes. In general there is a very strong need for processes that can be adapted to the needs of different materials and for machines that can be programmed or configured to perform different processes.

In addition, there will be an increasing need for new ways of joining different materials. Accordingly, adhesives are expected to gain in importance in car manufacturing. Newly developed adhesives that are resistant against oil are allowing the increasing use of this technology in car manufacturing. In addition to its suitability for multi-material design, adhesion is reducing weight and increasing stiffness. Especially photo-bondings (adhesives hardening under light) seem to be of growing interest.

Other promising joining technologies for different materials in cars like collar joining and different variants of snap fastening are arising. These processes are nonthermal, do not need any lubrication and can be combined with adhesives. Also coated materials can be joined.

The need for specific materials for specific functions will lead to an increasing integration of materials design into the design of manufacturing processes. Costs will be reduced by adapting processes especially designed for specific materials. There will be a simultaneous optimising of product, process and material properties. In this optimisation, modelling and simulation will play a very important role. A number of experts named the improvement of the interface between production, process and material properties via simulation as a prime research issue in order to enhance competitiveness of car manufacturing.

From a recycling point of view, multi-material design is highly problematic. The more different materials are being used in a product, the more difficult and expensive are the re-manufacturing and recycling processes. Neither is it clear how different new joining technologies relate to recycling demands. Nevertheless, recycling can be enabled by some measures like labelling the materials used and consideration of re-manufacturing at the development of new joining methods. For example, some adhesives are loosening when heated and this enables easy recycling. This aspect should be stressed in any research support measure. Accordingly, joining technologies for new materials with a view to recycling ability were also considered as one of the two most important cross cutting issues for research priorities by the automotive group at the scenario workshop.

Processing of Lightweight Materials

In order to reduce the fuel consumption, designers in the automotive industry are aiming at reducing the weight of cars as far as possible. By 2020, the weight of a car is expected to be reduced by 17% (250 kg). Accordingly, weight reduction is one of the main drivers of material selection in automotive industry. The following developments are generally expected:

- Body-Exterior: use of aluminium, magnesium and plastics in the very near future
- Body-Structure: metal foams (2003), steel/aluminium-space-frame (2004), sandwich-structure (2005), composites (2006), plastics (2015).

However, especially with respect to the body structure, it is by no means clear to what extent these advanced solutions will be applied. Some of these technologies might be confined to niche-cars and there are experts who reckon that the conventional steel frame will stay on the market for quite some time. When manufacturers have decided for a certain materials concept for car bodies, they are likely to stay with it for quite some time instead of switching to the next trend.

Overall, experts expect a general increase in the use of aluminium and magnesium. Additionally, the emergence of other lightweight materials is expected in case the political background is characterised by a high degree of concerted policy.

Magnesium

While magnesium is considered to have increasing importance but is confined in its use for niche applications, aluminium is widely expected to be of growing importance in all areas of car manufacturing. However, some studies are expecting a rise of average magnesium share in a car from the current ca 2.3 kg up to 113 kg. There are advantages with magnesium such as the low weight (one third of the weight of aluminium), but also disadvantages such as high costs and safety problems in processing the material. Nevertheless, prices are expected to fall from around 2010 due to expanded use of resources in China.

Aluminium

As the first car manufacturer, Audi started with mass manufacturing of aluminium bodies for the A2 in 2000.

Examples for advanced aluminium applications in cars:

Components	**Processes**
Door: Range Rover, Opel Omega Audi A3	die casting, extrusion, press joining: welding, riveting, screwing, laser welding
Motor parts	Sintering
Full body: Audi A8, A2	Hydroforming, laser welding

The use of aluminium depends very much on the development of adequate processing technologies. High investments are necessary to switch to a new material in car manufacturing. For example, it is reckoned that Audi planned for five years and invested more than 150 million Euros for their new aluminium manufacturing site.

For aluminium, the main processes being currently under investigation are: laser processing (detailed discussion see below), extrusion processes (see material strand report by CMI), hydroforming, flow-forming (a kind of rolling which is done immediately after casting), compact-spraying (a powder-metallurgy process), foaming and sintering.

From the environmental point of view, there are two aspects to be considered with respect to aluminium. On the one hand, it needs a high amount of primary energy for its production. On the other hand, it can be reused at a high energy level which gives it an advantage over plastics in recycling (magnesium has roughly the same advantage). Overall, with increasing taxes on energy use, aluminium is becoming a more expensive material.

Steel

Some interview partners pointed out that the variety of steel offered is steadily increasing which means that there is also a high potential for light weight steel applications in the automotive sector. In particular, highly compact steel products are competing with aluminium. Because of their high strength, their use is also inducing important weight reductions. In addition, steel is cheaper than many other materials and easy to recycle. The steel industry has started a special initiative to develop steel light weight concepts for cars and promote it to the automotive industry (ULSAC – Ultra light steel auto closures).

Plastics

There is a heavy competition between plastics, composites and light metals to be used for several purposes in personal cars. Several car manufacturers have started to use plastics for parts of the body.

There is particularly one possible usage of plastics, which could lead to a disruptive change for automotive manufacturing. If plastics can be coated and coloured “from the beginning”, paint-shops that today account for a substantial part of the automotive manufacturing process might vanish.

Nevertheless, the use of plastics raises several questions with respect to recycling. To make re-use possible, it is important to use only a limited number of plastics and to label the components

Other materials

Hybrid materials like foamed metals are also expected to gain importance but composites and hybrid materials are generally difficult to reuse. It is therefore recommendable to integrate recycling considerations into research projects dealing with light weight construction, just as for multi-material processing.

Regarding new materials, as one of the interviewees pointed out, there are several possibilities for weight reduction that have not even been investigated by now because of high costs. For example, titanium has a high potential as a light weight material but is much too expensive at the moment. Another promising material that is considered for automotive applications only in very pre-application projects is carbon composite, which is expected to bring weight reductions up to 40%.

Laser

The necessity to use plastics, hybrids and composites has brought about a variety of new processes. A key technology for processing light weight materials is laser processing. Laser welding has revolutionised the manufacturing of cars as several materials can be welded with a high degree of safety and exactness. The application of laser welding in serial manufacturing is rising at the moment and is expected to be further expanding according to literature as well as by several of the experts interviewed. While laser welding and cutting of conventional blank sheets and laser cracking of motor parts are already widely implemented, the processing of innovative materials like foamed metals is currently under way. Application of laser technology to plastics and composites as well as to several alloy metals and hardened materials is heavily investigated at the moment and even processing of copper for electronics applications is considered. For example, regarding plastics, VW is using laser welding robots for cutting covering plastics. Automotive suppliers are increasingly using laser welding for plastic housings (e.g. of electronic components). Furthermore, laser soldering and laser welding for micro applications like sensors are being tested.

For all these advanced applications, process control and quality control are key issues. Digital image processing is essential for testing welding seam quality. Sensors are of high importance to enable such control concepts as a variety of parameters have to be surveyed with a high degree of exactness. Furthermore, new kinds of laser sources have to be investigated to allow further applications.

Apart from the mentioned positive aspects on safety, laser technology is also advantageous for high degrees of automation and supports process integration. Furthermore, it is extremely fast and flexible. Because no tools are needed, there is no wear out. Laser technology therefore seems to be a key process for competitiveness of manufacturing of personal cars in Europe.

As one expert mentioned, not all manufacturing processes are equally easy to automate and therefore suitable for production in high-wage locations. Therefore, choice of materials which go along with certain processes has an impact not only on the nature of the jobs in car manufacturing but also on the location of these jobs. The expert thought the application of highly automated light weight manufacturing essential for the survival of European car manufacturing.

In summary it can be concluded that there is a multitude of trends in light weight construction and that some developments are heading in different directions. At the moment, it can not be foreseen in which state light weight construction in car manufacturing will stabilise. Nevertheless, it is clear that the direction of change will have major impacts in the following areas:

- car manufacturing processes and therefore on the opportunities for machine tool manufacturers and automotive suppliers
- recycling possibilities and environmental burden
- employment issues

Accordingly, there is an urgent need for innovative concepts for light weight design and manufacturing that takes into account the whole vehicle life cycle including manufacturing. Therefore, in the interest of competitiveness and sustainability, it is highly recommendable to investigate this area more closely. The high degree of uncertainty at present about life cycle developments at the same time makes it possible to actually affect developments in this area. For example, it might be worthwhile to invest into one of the more far reaching alternatives instead of risking a lock in into half-way solutions. At the same time, some solutions that seem to be very advanced with respect to weight reduction might lead to outsourcing of manufacturing operations or bring up new recycling problems.

Possible Adoption of Nanotechnologies

As sensor technologies are considered to be of high importance for the cars themselves as well as for manufacturing processes, nanotechnologies that enable smaller sensors with higher sensitivity would allow for major progresses in the automotive sector. Example of applications mentioned by the experts were how sensors could be used to tell the driver when he comes too close to the car in front of him and when to brake or not etc.

Other impacts are expected with nano-powders that help to improve powder-metallurgy methods. This would certainly have an effect on the industry since powder-metallurgy is widely expected to be increasingly used in car manufacturing. Nevertheless, is has to be diligently considered if or how nanopowders can be recycled. If this issue can not be solved, these methods are not likely to be taken up in the automotive sector since there is a strong pressure to recycle large parts of old cars.

In the interviews, the main issue raised in connection with nano-technology was coating and painting. The majority of the automotive experts that were interviewed expected applications of nanotechnology in car manufacturing in the time period up to 2020 in this area.

New coatings for chassis and body as well as for other parts, which would result in harder and stronger material would at the same time allow for thinner materials and, thus, lighter cars.

There is a major effort of car manufacturers to replace current coating methods to reduce VOC emissions. Several car manufacturers have developed alternatives to classical painting methods, but most of them are still difficult to apply universally. Therefore, the use of nano-coatings, especially for plastics, is highly interesting. Furthermore, nano-coatings are expected to bring new improved surface quality and to add interesting features to the surfaces.

Examples for this are:

- Dirt repellent coatings for lights and window screens
- Self cleaning coatings
- Shining foils
- Tire coatings improving adhesion

Moreover, with nano-coatings used to improve tooling, this will be of high importance to the automotive sector due to the fact that new tools are needed to meet the increasing demands on fast processing of different materials. New tool coatings would be even more interesting – due to cost considerations as well as to environmental concerns if coolants or lubricants can be avoided or reduced through their use.

7.3.2 Customer

As drivers spend greater amount of time in their cars, they are starting to demand equivalent levels of connectivity in cars as they would have at home or in the workplace therefore electronics and control will become a large part of the automotive industry. The following will summarise the trends that will happen relating to electronics and control.

Electronics and control

- The use of semiconductors and sensors is expected to grow dramatically. Demand for sensors to measure, monitor and track virtually all activity in a car is growing, spurred by the incorporation of more electrical systems in cars
- The future will see more business links between the automotive and telecom industries to offer in-vehicle communication services
- The value of electronics and software in new vehicles will continue to increase, in areas such as control and intelligence, telematics, information and service provision, entertainment and user interfaces.
- Telematics shows great promise in bringing increased convenience and security to consumers by connecting cars to the world outside. Although high costs are limiting its use, it is likely to find greater demand as stricter government regulations and increasing demand for consumer safety cause prices to drop.
- Effective manufacturing and management processes and systems are a key competitive factor, in terms of efficiency, effectiveness and pricing. Of particular importance are processes associated with research, design, new product development, manufacturing and service provision.

7.4 International Research

In terms of looking at international trends and aspects related to technology development, Germany and the UK were selected as examples to look at closely. Germany was chosen for its obvious leadership in the automotive industry and its technological innovativeness. The UK produced the Foresight Vehicle Report, which is a collaboration between industry, academia and Government to identify and demonstrate technologies for sustainable road transport. The Foresight Vehicle Report was consulted extensively in terms of this project’s requirements, specifically in the identification of new technologies. The UK also has a global reputation in terms of its expertise in the niche motor sport market.

In the case of Germany, this report details in Section 5.1. the various Government Support mechanisms that have been introduced to elevate and contribute to the innovativeness and competitiveness of the automotive industry in that country.

Malaysia was not researched per say, but special attention was paid to the Malaysian government's support of the automotive sector and special mechanisms that were introduced to grow and sustain this sector. This should be viewed in the context of Malaysia being an emerging economy.

7.4.1 Germany

Germany's economic strength has been based on car production to a great extent. The automobile industry is one of the dominating sectors because many economic activities rely on, and are linked to automobile production (i.e. tyre industry, plastics industry, metal processing). If you include suppliers, car services, garages and retailers, a total of about 5 million employees (1 out of every 7 jobs in Germany) depend on the success of the automobile industry

The sector contributes 5.3% of GDP and 28.6% to manufacturing GDP.

In terms of German Research and Development expenditure, the automotive sector accounts for 1/3 of the total, this equates to some 15 billion Euros per annum. These funds are provided by Industry and Government, and the contribution allocation is 60% and 40%, respectively.

The German government has introduced a number of support mechanisms and policies to ensure the competitiveness of the automotive industry. These include:

- Location support/cluster development
- Tax relief on environmentally friendly fuels
- Specific R & D projects for new technologies
- Initiative by Federal State to provide consultancy support services to regional automotive related companies

Lessons learnt from Germany

With changing technologies, production concepts, strategies and products, the German car industry is often an initiator of innovations in other industries. Its success has been due to the technological competencies of manufacturers, suppliers and their respective employees.

German government, together with the automotive industry, has introduced several mechanisms or support programmes to grow the industry.

7.4.2 United Kingdom

The automotive sector has provided a major contribution to the UK economy, with car production and sales reaching record levels (total UK car production in 2000 was 1.64 million units, expected to rise to 1.87 million in 2004). The sector contributes approximately 1.5% of GDP and employs some 715 000 people – both directly in vehicle manufacturing and in the supply and distribution chains. About half of added value comes from manufacturing and assembly, which represents about 15% of total UK manufacturing added value.

The UK sector's particular strengths include design engineering, especially advanced technology in motorsport, with 80% of the world market. Motorsport currently has a 5 billion Pound turnover (of which more than 50% is export sales) and the sector employs over 40 000 people, of which 25 000 are highly trained engineers in more than 3 000 businesses.

Foresight Vehicle is the UK's national automotive R&D programme aiming to promote technology and to stimulate suppliers to develop and demonstrate market driven enabling technologies for future road vehicles which must satisfy increasingly stringent environmental requirements as well as meeting expectations for safety, cost, performance and desirability.

Lessons learnt from the UK

UK leads the world in automotive performance engineering. As a result most Formula One cars are produced in the UK, as well as many NASCAR and Indy vehicles and engines. Skills and expertise are the main reasons why the UK automotive sector attracts such a high level of inward investment.

7.4.3 Malaysia

Lessons learnt from Malaysia

To help the domestic automotive industry meet the challenges of market liberalisation, the Malaysian government is implementing several measures to increase the competitiveness of the local automotive industry.

Some of these measures include:

Approval for new projects for all categories of vehicles will be allowed, in order to attract inflows of new investments and expansion of projects in the automotive industry

Special programmes to enhance competitiveness of components and parts manufacturers will be devised by the Ministry of International Trade and Industry

Seeking more collaboration or joint ventures with internationally renowned automatic component manufacturers in Research and Development, with emphasis on engineering design

Grants to Small Medium Enterprise (SME) to improve product and upgrade engineering capabilities

7.5 Technology Identification

The table below represents graphically the leading technologies identified by the various countries' experts as imperative for the sustainability of the automotive sector. The information was gathered from international and the South African research.

Table 21: Technology identification

Technology description	Germany	UK	SA
Structures and materials Examples: Biodegradable materials, environmentally friendly materials, lightweight material, auluminium, titanium, plastics	X	X	X
Hybrid, Electric & alternatively fuelled vehicles Examples: Fuel cell technology, electrical power generation in automotive, environmentally friendly vehicles in production	X	X	X
Sensors, electronics and telematics Examples: Web based manufacturing, Intelligent electronic systems, adaptive control systems, car security systems	X	X	X
Design & Manufacturing processes Examples: Multi-material components, hydroforming, injection moulding, tooling, hybrid & composites for specific applications	Not selected - Design potential small in the future - Focus will be on module strategies & reduction of vehicle parts	X	X
Engine Manufacturing technologies Alternative fuels	Not selected Focus is on alternative fuels	Important Development of new engine materials	

From the above it can be seen that there is consensus on what the technologies of the future are for the automotive industry. These technologies will be described in detail in the following section

7.6 Leading Technologies

7.6.1 Identification of technologies

The following technologies are regarded to be of importance for the future development of the South African automotive industry:

- Lightweight materials
- Hybrid, Electric and alternatively fuelled vehicles
- Sensors, electronics and telematics
- Design and manufacturing processes

7.6.2 Detailed description of technologies

7.6.3 Lightweight Materials

The need for, and benefits of lightweight materials are driven by three primary factors:

1. Reduction of emissions of air pollutants and greenhouse gases
2. Creating better performing and riding vehicles
3. Economic benefits for those countries/manufacturers who become leaders in the technologies.

Lightweight materials are essential for battery and fuel cell electric vehicles. For example, using current materials, a fuel cell Ford Focus weighs approximately 1,750 kg, which is more than 50 percent heavier than the same vehicle with an internal combustion engine. Unless the weight of fuel cell vehicles can be reduced significantly, much of the potential improvement in fuel efficiency of fuel cell vehicles will be lost. In short, commercialization of fuel cell vehicles will not be feasible without the extensive use of lightweight materials.

The innovation challenge is to reduce costs throughout the supply chain of materials production and component manufacturing, coupled with advanced vehicle design and assembly approaches for producing reduced weight vehicles that have new and improved features and benefits that make them marketplace winners.

The benefits of reduced vehicle weight are:

For every 10% in weight reduction, there is a 6-8% improvement in fuel efficiency

This translates into about 17-20kg reduced CO2 over the lifetime of the vehicle per kg weight reduction

Reduced weight also allows for easier braking, and improved responsiveness

Lighter vehicles carry less momentum into collisions

Light weight is critical to novel energy supply systems such as fuel cell vehicles

The use of lightweight and high-strength materials is growing steadily. Aluminum production has increased by a factor of 25 since 1940. Production of magnesium diecast automotive components has increased at a rate of 12-15% annually since 1993, and future use of magnesium (Mg) in vehicles could grow by 20% annually. The use of new, advanced steel in vehicles nearly tripled from 1977 to 2000. Revenue growth will be even higher due to the innovative use of design and technology. Overall growth in shipments along the chain has been strong, doubling from 1993 to 1999.

The areas of application include the vehicle body structure and any frames or structural chassis components.

The key market drivers for the introduction of lightweight materials are:

- Minimizing energy and emissions during production at all stages,
- Increased global demand for more fuel efficient vehicles,
- Maintaining or improving safety and performance of vehicles,
- Improving vehicle recycling and the use of recycled materials,
- Meeting consumers' demands for durability, utility, aesthetics and cost competitiveness while reducing vehicle weight (requiring new materials with advanced properties),
- Meeting designers' needs for greater flexibility in choice of materials,
- Reducing costs and time to market, requiring computer simulation of novel processing techniques and innovative materials.
- The requirements for light weight materials development implies R&D capacity to optimize materials, and introduce new, lower-cost, lower-weight designs and processes for components and whole subsystems.

7.6.4 Hybrid, Electric & Alternatively fuelled vehicles

The following chart provides a detailed description and information relating to hybrid, electric and alternatively fuelled vehicles.

Table 22: Hybrid, electric and alternatively fuelled vehicles

Alternative Fuel	How it works	Major suppliers	Mass Market
Fuel Cells	Hydrogen is extracted from gasoline or methanol and then combined with oxygen to produce electricity which is stored in the fuel cell.	Ballard Power Systems, GM, Ford, DaimlerChrysler, Honda, Toyota	Not likely until 2010 at the earliest. Raw material costs are high and storage of hydrogen remains a problem.
Hydrogen	Liquid hydrogen is used as an alternative fuel to gasoline or diesel in the traditional internal combustion engine.	BMW	To take at least five or six years. Is a realistic long-term alternative to fuel cells as is more compatible with current internal combustion energy technology and gives better car performance. Problems remain as regards storage and provision.
Hybrid	Powered by an internal combustion engine combined with an electric motor.	Toyota	Toyota

Liquid Petroleum Gas	As hydrogen can be used as a direct alternative to gasoline or diesel in conventional internal combustion engine.	Not applicable. All vehicles can be converted for use	Now on the market, although cars need to be converted for supply. Most likely alternative fuel solution in the short term because of compatibility with internal combustion engines.

USES OF FUEL CELL TECHNOLOGY

The following are press releases that demonstrate the areas where fuel cell technology is being used and developed for commercial applications:

Boeing to Explore Fuel Cells for Commercial Airplanes. Boeing Commercial Airplanes will develop and test a fuel cell-powered single-engine airplane that would use an electric motor to turn a conventional propeller, in order to evaluate fuel cells for future Boeing products. Boeing is ultimately interested in exploring the use of fuel cells to replace the gas turbine auxiliary power units in commercial transports

Suzuki Unveils Fuel Cell-Powered Two-Seater at Tokyo Motor Show. Suzuki unveiled a fuel cell-powered Covie two-seater at the 2001 Tokyo Motor Show. The vehicle features a General Motors fuel cell stack, and uses natural gas as the fuel.

Diahatsu Presents MOVE FCV-K-II. Diahatsu presented the MOVE FCV-K-II, a four-seater fuel cell mini-vehicle that uses a high-pressure hydrogen storage tank system. The MOVE FCV-K-II uses a 30 kW Toyota fuel cell stack, installed beneath the floor at the rear of the vehicle.

Manhattan Scientifics Wins Award, Introduces Fuel Cell Scooter. Manhattan Scientifics' fuel cell bicycle, designed by Italian bike maker Aprilia S.p.A with a fuel cell from the NovArs unit of Manhattan Scientifics, Inc., has been named one of Time Magazine's "Inventions of the Year 2001." The bicycle stores compressed hydrogen in a 2-liter canister in the frame and has a range of about 50 miles, twice as far as electric bikes, and a top speed of 20 miles per hour. The bicycle is expected to be available in 2003 with a price tag of approximately $2,300. Manhattan Scientifics has also recently completed initial testing of an environmentally friendly electric scooter, powered by the company's 3-kilowatt (kW) fuel cell. The hydrogen-fueled fuel cell is capable of powering the vehicle for a total of 120 miles before refuelling and is able to propel the scooter at a top speed of 35 miles per hour.

Ballard and Ford Sign US$43.9 Million Agreement. Ballard Power Systems has signed a three-year agreement valued at US$43.9 million with Ford Motor Company to supply fuel cell engines and support services. This order brings Ford's total recent orders to over US$63 million

Caterpillar and Fuel Cell Energy Announce Fuel Cell Agreement. Caterpillar Inc. and FuelCell Energy have signed an agreement to distribute fuel cell products for industrial and commercial use, and to jointly develop fuel cell systems, including highly efficient hybrid products integrating Caterpillar's turbine engine technology.

Fuel Cells Installed on Long Island. The Long Island Power Authority (LIPA) has successfully installed 55 fuel cells manufactured by Plug Power. Currently, 18 of the 55 fuel cells are fully installed and generating electricity for LIPA's grid.

ADVANTAGES OF FUEL CELL TECHNOLOGY

The following lists the advantages of Fuel Cells usage:

Zero emission and silent

Fuel Cells are addressed as "zero emission" technology. This is one of the reasons why fuel cells are attractive. They can be used in virtually any location, even there where normal power production is not possible due to emissions of pollutants and noise.

High efficiency

Fuel cell systems produce electrical energy at very high efficiency. Generally, the efficiency is better than that of generators powered by internal combustion engines such as piston engines and gas turbines. Only large combined cycle power plants can outperform fuel cells. However, if high electrical efficiency is required, fuel cells can be combined with gas turbines, thereby surpassing the efficiency of combined cycle systems, while maintaining zero emission characteristics. Due to the ability to integrate power production in dwelling areas, efficient use of the waste heat is possible.

Fuel diversification

At present, the energy source for transport is oil. Fuel cells prefer hydrogen, which can be made of virtually any fossil fuel source, from biomass, and from electricity derived from e.g. wind and solar energy. These will very like be the energy sources of the future. Thus, fuel cells help to reduce the dependence of oil, and enable the transition to a sustainable energy system.

Enabling technology

Fuel cells enable new products or allow industries to completely redesign existing products. A nice example is given by General Motors, which has presented a complete new approach in car design. The new design can only be realized using fuel cells.

COMMERCIALISATION OF FUEL CELL TECHNOLOGY

In terms of commercialisation of the technology, the following questions are posed with answers:

- **Are fuel cell systems available on the market?**
  - Fuel cells are still experimental technology. They are not mass-produced, only hand-built in small quantities. The goal now is to make them smaller and less expensive to produce.

- **When will fuel cells be ready for the residential market?**
  - Given the present state of the market our best guess is that fuel cells may be commercially available for residential use around 2010. About two years ago the industry was trying to have commercial units ready by 2005, but progress has been slower that anticipated. The bottom line is that testing, research and fine tuning will be continuing over the next several years

- **What is the US doing in terms of research and development of alternative fuels?**
  - In his State of the Union address, President Bush announced a $1.2 billion hydrogen fuel initiative to reverse America's growing dependence on foreign oil by developing the technology for commercially viable hydrogen-powered fuel cells to power cars, trucks, homes and businesses with no pollution or greenhouse gases. The hydrogen fuel initiative will include $720 million in new funding over the next five years to develop the technologies and infrastructure to produce, store, and distribute hydrogen for use in fuel cell vehicles and electricity generation

Sensors, electronics and telematics

Sensors, electronics and telematics technology aims to improve the safety, security and comfort of all road users. Systems already developed in this field allow a vehicle to automatically adapt its cruise speed to allow for vehicles ahead.

Research projects are developing the ability to avoid pedestrians or obstacles in the road and to extend the capability of a car and its driver to adapt vehicle speed to the road situation and traffic.

With increasing traffic volumes and hectic lives then journey time reliability is an increasing concern, both for travellers and freight. Location based services, route guidance and increasingly customised information provision assist in avoiding traffic congestion. This improved transport efficiency can also translate into environmental benefits; shorter journeys leading to reduced pollution.

To deliver many of the envisaged benefits fully, more co-operation will be required between vehicles and between each vehicle and infrastructure services. This will rely upon direct communication between these elements on the highway, sharing the information signalling intent.

Sensors

The global market for automotive sensors grew by 8% in 2002 to $7.8bn and it is expected to reach $8.2bn in 2004, driven by a combination of a slight increase in vehicle production and increased demand for sensors in electronic control of the engine, its emissions and safety, comfort and convenience functions within the passenger vehicle.

Electronics

The continuing process of making automobiles smarter is dependent upon increasing the use of electronic systems in them. In the automotive electronics sector, the development and operating life cycle of the electronics systems used are considerably longer and more stringent than those for mass-produced electronic components commonly available. Electronic systems are required to function reliably at all times throughout the entire life of an automobile. This gives rise to special requirements for the electronics used in this industry from the manufacturers' point of view. Unique operational conditions for guaranteed reliability over longer and harsher life cycle profiles in hostile environments necessitates the use of special qualification and testing techniques and quality controls.

Telematics

Telematics can be defined as a combination of wireless voice and data communication systems aimed at providing drivers with safety and information including automatic airbag deployment notification, vehicle tracking, personalized information, real-time traffic data, emergency aid, and entertainment from a central service center. Innovative features include Internet access, voice activation, and the ability to control the car audio and climate control.

Technological innovation will increasingly be a key element of an export-led automotive industry. In this regard, a key focus area is that of opportunities in the new generation of telematics, for example:

Futuristic technologies

- Intelligent distance-sensing cruise control systems
- Night visibility capabilities
- Peripheral monitoring systems
- Interactive communication services from e-mail, vehicle theft tracking and route guidance

Telematics will provide ongoing improvements in the design and functioning of future cars. It will be a major competitive differentiator, representing the biggest step forward in the automotive industry, changing everything about how vehicles are designed, maintained, services and insured. South Africa has a first-world information technology infrastructure. There are opportunities for investment in state-of-the-art production facilities for automotive-related telematics production. (Current Developments in the Automotive Industry, September 2003, TISA & MIDC)

7.6.5 Design and manufacturing processes

The above is concerned with the ability to develop innovative solutions in the areas of vehicle design and manufacture, considering all aspects of the vehicle life cycle. The pressure to be economically 'lean and mean' also means that we must consider the life process of a vehicle from beginning to end (the point at which recycling or regeneration has occurred). The design and manufacturing processes must, therefore, encompass processes which occur after the vehicles (or components) have reached the end of their useful life.

Manufacturing

Improved manufacturing systems are crucial for achieving the goals of reducing energy and material consumption, reducing emissions, and increasing efficiency and competitiveness. Aspects that require attention include component-level manufacture and assembly, system-level manufacture and organisation, management of manufacturing systems, together with commercial and market considerations.

Integration

Systems integration is crucial if significant improvements to overall life cycle performance of road vehicles are to be achieved. This includes consideration of how the various vehicle sub-systems operate together, how the vehicle is designed, manufactured and operated, and how the information and knowledge that enables these systems to function can be combined more effectively and efficiently.

Other areas of technology development may include:

- Shift to service (reduced car ownership)
- Reduced vehicle size
- Increasing software and electronics
- Human-machine interface (in vehicle and manufacturing)
- Increasing automation

7.7 Conclusion

Technology and innovation play a vital role in the automotive industry. This is illustrated by the fact that there are more computers aboard a car today than was aboard the first spaceship. A new car has an estimated 10-15 on-board computers, operating the engine, radio, brakes, transmission, steering systems and other components.

In terms of this study, four technologies were highlighted as being critically important for the continuous development and growth of the automotive sector. These are:

- Development of lightweight materials
- Development of alternate fuels e.g. fuel cell technology
- Sensors, electronics and telematics
- Improved design and manufacturing processes

Design and manufacturing of light weight materials

- titanium extraction (lower price)
- joining technologies for different light weight materials with view to recycling / re-manufacturing
- coloured plastics (alternatives to classical coatings)

Advanced manufacturing processes

- laser technology
- mechatronic
- rapid manufacturing, rapid tooling
- nanotechnology for coatings, sensors, and catalysts
- hydroforming (or other methods for varying material thickness (in the same piece)
- soldering without lead (process control, quality assurance)
- manufacturing of multi-material components (with an integrated assessment of sustainability concerns like recycling and emissions but also effect on working conditions in manufacturing).

Near net shape processes

- powder-metallurgy, sintering (especially application oriented, view to recycling important)
- rapid manufacturing
- closed mould injection processes (aid small companies)

Process simulation

- simulation of new materials as well as simulation of the interface between tools and materials
- simulation of forming processes especially bending e.g. of magnesium. Actors from software suppliers as well as manufacturers have to be involved

Planning and control of manufacturing processes

- methods for recycling environmentally friendly product and the process design needed in order to produce them
- integrated automation concepts
- control technologies with adequate sensors (especially for welding and bending)
- standards for electronic systems as well as for software and control systems
- man-machine interfaces
- virtual reality for planning of manufacturing (with a view to social sustainability aspects)
- simulation and expert systems to aid quality control in electronic systems production (reliability-simulation), especially for soldering. Possible research constellation: European user and provider companies in soldering. This project would especially aid soldering without lead.

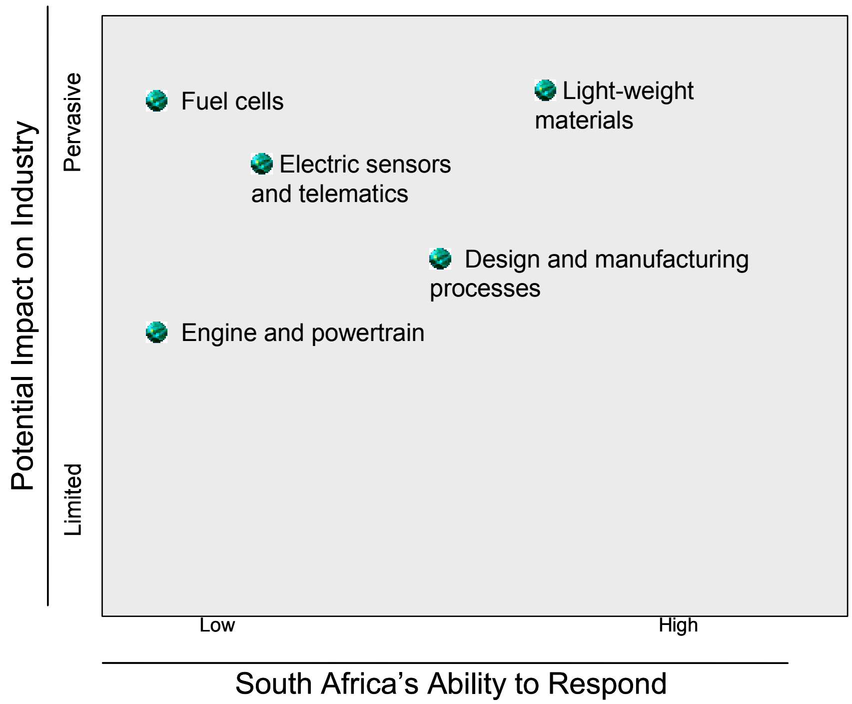
Taking all of the above into consideration, the matrix below represents a summary of the technologies identified as important and that should be taken into consideration for further development

Table 23: Technology positioning analysis

Technology	Technology requirements	South Africa's position to take advantage of the requirements
Development of lightweight materials	Increased use of aluminium and magnesium Fundamental understanding of the physical and structural properties of light metals Access to enabling technologies R & D to ensure improved metal quality Availability of relevant education & training to ensure a well-trained workforce	SA's position is strong because SA has a well developed aluminium industry and available raw material resources There will be a strong impact on the industry because SA is rich in raw materials like Aluminium, Magnesium, Plastics and Titanium. Also has resources of hybrid materials like foamed materials The Government can take advantage because the industry development will include the development of market opportunities through local and international investment and technology transfers to enhance the establishment of new enterprises in the industry There will also be possibility of identifiying and exploitating opportunities for black economic empowerment and SMME's
Development of electric, hybrid & alternatively fuelled vehicles	Development of the broad range of skills necessary for fuel cell development including the chemistry, control electronics, production methods and software development Invest. in R & D Changes in manufacturing technologies	SA's position to take advantage is weak due to lack of Fuel cell technology skills as well as funding for R & D There is an implication of technical changes throughout the sector and demand will shift away from mechanical parts to process-technical and electro-technical components

Development of electronics, sensors and telematics	Electronic production must become a new core competency Mechatronic skills must exist Development of appropriate systems architectures and standards	The position to take advantage is medium due to electronic production competence and mechatronic skills. Car manufacturing technologies will change therefore the impact will be high.
Development of design and manufacturing processes	Improved manufacturing systems in terms of reducing energy and material consumption & reducing emissions	SA's position is high in terms of this technology because it currently has strong manufacturing capabilities. The impact will be medium because SA will need to adapt manufacturing technologies in terms of recycling, etc. Once again the Government can take advantage of this because the industry development will include the development of market opportunities through local and international investment and technology transfers to enhance the establishment of new enterprises in the industry. There will also be possibility of identifiying and exploiting opportunities for black economic empowerment and SMME's

Figure 13: Impact analysis grid



In light of the previous table, the following grid positions the identified technologies in relation to its relative impact and South Africa's position in terms of technology requirements.

The grid highlights quite clearly that the South African automotive industry, taking cognisance of it's strengths and competitive advantage, should pursue the development of technologies in lightweight materials, electronics, sensors and telematics and design and manufacturing processes.

7.8 Technology Support for Sector Development

This sections highlights programmes and support for the automotive sectors in Germany. It also points to concerted efforts made to enhance the competitiveness of the sector in that particular country. A short description of support programmes currently available in the South African automotive industry is also given.

7.8.1 Germany

Location Support/Cluster Development

Objectives of this mechanism

- To develop the state of Saxony as an attractive economic location
- To establish research development programmes

- To increase exports
- Long term objective is to preserve the automotive industry in Germany
- To create new jobs, especially in Eastern Germany
- To boost the competitiveness and innovation of the regional economy

Motivation for selection of this particular mechanism

- Establishment of a sub-contractor industry
- Prevailing job environment in Eastern Germany
- To develop new technologies
- Completely new products may be developed and gaps in existing value chains can be closed

What were the results

- Improved Infrastructure
- Cost reduction due to less stock keeping – car manufacturers and sub contractors work together
- Synergies between companies (network, shared R & D facilities)
- Large potential of highly qualified workers
- Proximity of technical Universities

Tax relief on environmentally friendly fuels

Objectives

- Pollution control
- Incentive for consumer to buy environmentally friendly cars
- Need to find alternative fuel source

Motivation for selection

- Compliance with environmentally friendly policy in Europe
- Keep up with technological progress on global scale

What were the results

- Promotion of environmentally friendly technologies
- In terms of the 42 million passenger cars in Germany, 33% are already compliant with most stringent emission standards
- In terms of registration of new cars, 85% of cars meet most stringent standards already

R & D projects for new technologies

Details of Programme

Materials Innovation Programme : “WING: Werkstoffinnovationen fur Industrie und Gessesschaft” – 250 m Euros Federal Government support by Ministry of Research & Development

“Leitinnovation: NanoMobil” which is a promotion of research and development projects concerning the nanotechnology within the automotive sector (themes include security, sustainability, competitive capacity and comfort)

The above projects are supported by non-payback benefits: where industry and government support equal 50% each

Objectives

- Reinforcement of nanotechnology as a driving technology
- Combination of nanotechnology with other technologies
- Integration of nanotechnology within the automotive sector

Motivation for selection

- Reinforcement of the innovation capacity of the automotive sector
- Industrial value of new materials for development and industrial applications
- Economic value (leverage effect on market growth and employment incentives

- Use of R & D for sustainable development

Results

- Development of better product characteristics
- New application potential along the value chain
- Bundling of research activities for nanotechnology applications
- Value for co-operating R & D partners/industry participants

Initiative by Federal State

Details of Programme

- Informative Internet portal financed by Federal State
- Support of consultancy by Federal State to provide services to regional automotive related companies e.g. consulting (strategy concepts), managing (process optimisation & implementing of new strategies, engineering (solution development), assistance (visits to trade fairs, application for aid money offered by German Government i.e. German Ministry of Education & Research, Department of Trade & Industry), Financial support for Technology & Innovation: 35% (up to 50% by infrastructure lacking regions) and Financial support for manager qualifications

Objectives

- Assistance by professional consultancy
- Bundling of company information of the region (manufacturer, supplier, products, services)
- Platform for internet links (e.g. organisations, chambers of commerce)

Motivation for selection

- Support of regional automotive industry
- Reorganisation of automotive sector
- Pressure of SMS companies to focus on their key competences
- Underdeveloped market research of region

- Reinforcement of the innovation capacity of the automotive sector

Results

- Development of network of companies
- Creation of 1000 new jobs

7.8.2 South Africa

The question now arises in terms of how does South Africa compare with the initiatives/support mechanisms that have been instituted in Germany to ensure that country's competitive edge in the automotive industry now arises.

MIDP (Motor Investment Development Programme)

The MIDP has been recognised around the world as a successful and innovative national strategy to develop automotive manufacturing and open up a domestic market to compete globally.

Gauteng Automotive Supplier Park

The Gauteng Provincial government launched a R1 billion Automotive Supplier Park outside Pretoria. The Supplier Park will group different technologies, suppliers and service providers for various customers. The Park aims to ensure the global competitiveness and sustainability of South Africa's automotive industry through shared services and improved logistics and automotive manufacturing processes. The Provincial government contributed R200 million and the private sector contributed R800 million

Investment projects initiated by TISA (Trade and Investment South Africa)

The investment projects on the TISA automotive investment pipeline amount to approximately R6,3 billion. Should all of these investment projects come to fruition, approximately 6 000 new jobs would be created in the industry (Current Development in the Automotive Industry, September 2003, TISA and MIDC)

Investment Incentives

The South African Government supports both domestic and foreign investments and has created a range of incentives designed to enhance the national and international competitiveness of South African business. Around 90 different incentive and assistance schemes are available to businesses.

The table below sets out the comparison between South Africa and Germany:

Table 24: Comparison between Germany and South Africa

German support Mechanisms	***South African support Mechanisms***
Location Support/Cluster development	Gauteng Automotive Cluster Automobile Supplier Park Current investment of R1 billion million by Blue IQ and Provincial government.
Tax relief on environmentally friendly fuels	
R & D Projects for new technologies	Activities at CSIR Automotive Industry Development Centre
Initiatives by Federal Government	MIDP

As can be seen, at first glance South Africa compares favourably with Germany in terms of support mechanisms. One has to consider, though, the amount of funding that each support mechanism in South Africa receives in comparison to our German counterparts.

AEROSPACE SECTOR

8 TECHNOLOGY DEVELOPMENT TRENDS OF THE AEROSPACE SECTOR

8.1 Summary

The Aerospace industry will always be a driver for technological and economic growth, and will always be seen as an incubator of critical and pervasive technologies" (Aerospace – meeting Canada's innovation challenge, September 2001 – Aerospace Industries Association of Canada). This statement basically moots the fact that a country's Aerospace industry has the capacity and capability to propel it to the top ranks of economic performance.

Taking the above into consideration, the South African government has stated clearly that it wants the Aerospace industry to be as healthy and vibrant as the automotive industry by the year 2014, and has the vision that by this date, South Africa will have a sustainable, growing, empowered and internationally recognised industry.

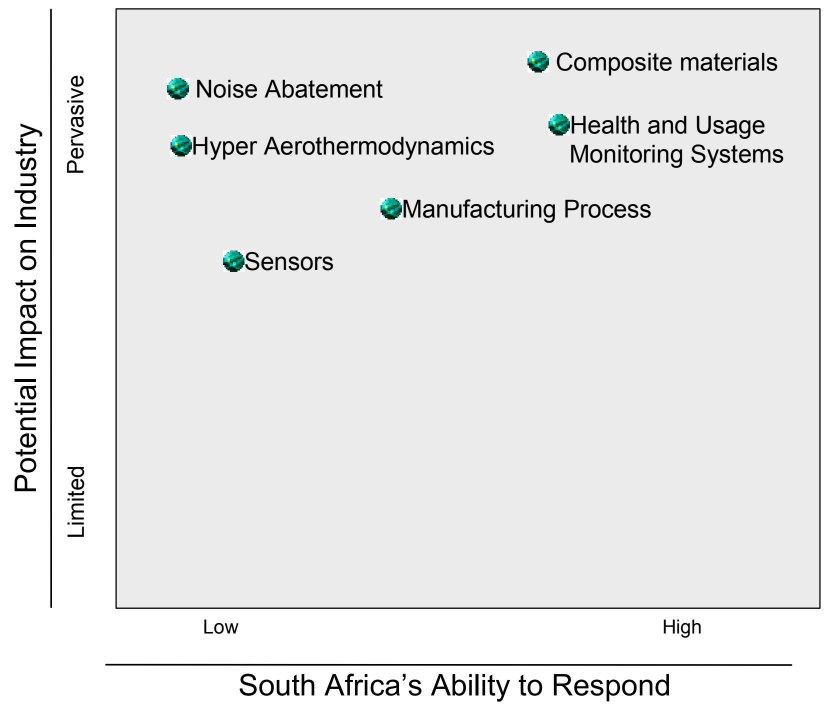
The South African Aerospace industry currently has vast capabilities as a result of the strategic funding used for military purposes over the last forty years. The South African industry has the ability to design and manufacture tier 1 complete systems like unmanned aerial vehicles. There also exist pockets of niche expertise in various Aerospace disciplines and sub sector activities. There is no doubt that the Aerospace industry can be a vital instrument in achieving the goal of making South Africa a leader of innovation and emerging technologies.

In terms of this study, four technologies were highlighted as being critically important for the continuous development and growth of the Aerospace sector. These are:

- Development of composite materials
- Development of hyper aero-thermodynamics
- Development of Sensor usage
- Health and Usage Monitoring systems
- Noise Abatement
- Improved manufacturing processes

The following grid graphically positions the South African Aerospace industry, in terms of these leading technologies, taking into account South Africa's relative strength in these various areas:

Figure 14: Impact analysis grid



The grid highlights quite clearly the impact and importance of composite materials and Health & Usage Monitoring systems (HUMS) technologies. South Africa's competitive strengths in composite materials and HUMS place it in a strong position to develop these technologies and become a leading global player in the Aerospace industry.

The following is a brief description of the above technologies:

Composite Materials

Advanced composites have emerged as the structural materials of choice because of their superior specific strength and stiffness properties. Benefits significantly lower operating and manufacturing costs, increased flight safety, and markedly reduced structural weight in Aerospace vehicles. Applied to major components, the weight saving which could potentially be more than 20% would have a marked effect on aircraft fuel burn, resulting in lower operating costs in addition to the environmental benefit from using less fuel per passenger-mile flown.

Health and Usage Monitoring Systems

HUMS are used to monitor process parameters such as engine temperature, oil temperature, oil pressure and chip detection. Provides a health status and enables monitoring of the flight system. The aim is to reduce downtime by having parts in place before their end of life.

In summary, South Africa has the capabilities, competence and expertise to become major players in these two technological areas.

8.2 Context of the Aerospace Industry

"The Aerospace industry will always be a driver for technological and economic growth, and will always be seen as an incubator of critical and pervasive technologies" (Aerospace – meeting Canada's innovation challenge, September 2001 – Aerospace Industries Association of Canada)

8.2.1 Definition of Aerospace industry

The Aerospace industry can be defined as follows:

The Aerospace industry is that industry which covers the Research and Development, design, manufacture, support, maintenance, conversion and upgrade of:

- Rotary and fixed wing aircraft,
- Satellites and satellite launch and tracking systems,
- Air traffic control systems,
- Unmanned aircraft,
- Weapons systems,
- As well as their relevant subsystems and components.

(Adapted from Paul Hatty, 2000)

The Aerospace industry covers both civil and defence aircraft.

Francois Denner, Chief Director of the Strategic Competitiveness Unit at the DTI defines Aerospace for the South African context as activities surrounding

- Defence
- Civilian
- Aeronautics, and
- Space

8.2.2 Global Aerospace Industry

The Aerospace industry is vital for

- Sustainable growth
- Incubating key skills and technologies
- Being a driver of technology
- And makes an essential contribution to security and defence

The international Aerospace industry is highly weighted towards the industrialised nations, with the United States the clear leader both in terms of world market share and employment numbers. The EU accounts for one third of all Aerospace business world-wide in terms of turnover compared with almost half for the US Aerospace industry. In 2000, the European Aerospace industry employed 429 000 persons directly and many more indirectly, with a consolidated turnover of 72 300 million Euros.

In 2003, worldwide commercial Aerospace sales were $4.9bn and defence and space related sales were $4,1bn. Traditionally, worldwide spend in the Aerospace sector has been 70% on defence and 30% on civil. This has changed dramatically over the last twenty years. Civil spend has assumed a greater proportion.**South African Aerospace Industry**

In the European Union (EU) Strategic Aerospace Review for the 21st century (STAR 21), it is stated that a flourishing and competitive Aerospace industry is essential to ensuring a secure and prosperous Europe. This must be true of all nations; South Africa definitely not being an exception. A flourishing and innovative Aerospace industry is vital to meeting a nation's objectives for economic growth, security and quality of life.

The South African Government has stated clearly that it wants the Aerospace industry to be as healthy and vibrant as the automotive industry by the year 2014, and has a vision that by this date, South Africa will have a sustainable, growing, empowered and internationally recognised industry (ASSEGAI – 2nd draft). As a result, the development of a National Aerospace Strategy is being pursued by various Industry players and Governmental institutions. The formation and launch of the Ministerial Task team is the next stage in the process.

The vision of the DTI is make the local Aerospace industry a high value addition sector, with improved capability and high value manufacturing that is part of the global Aerospace arena (Francois Denner)

The South African Aerospace aviation industry is an industry that was boosted during the long period of economic isolation. R & D funding was used to develop core technologies from scratch. This resulted in development mainly in the military sector which saw the design and manufacture of completely new military systems e.g. Rooivalk attack helicopter. The industry was also protected from external competition and it had a captured market. This has since resulted in a lack of international customer knowledge i.e. the industry lacks in terms of integration of systems and production to meet the demand of international customers i.e. do not understand what an international customer would require (ASSEGAI)

The industry now is highly fragmented with very little domestic co-operation between companies. There exist pockets of niche expertise like radar, castings, and airframes (to name a few).

- The South African defence industry is dominated by six research, development and manufacturing companies:Aerosud, ADS, ATE, Denel, Grintek, and Reunert.

They perform work across the defence and commercial sectors.

Denel Aviation is the biggest of the above listed companies and they are involved in design, manufacture and assembly. The following lists a few of their capabilities:

- Assembly of BAE Systems Hawk 100 advanced jet trainers
- Manufacture of tailplanes for hawks & other customers
- Assembly of Agusta A109 light utility helicopters for the SAAF
- Assembly of A109 7 A119 Agusta helicopters for Africa and certain Asian nations
- Manufacturing of major components for SAAB Gripen advanced fighter
- Design & manufacture of Rooivalk – attack helicopter

The South African commercial Aerospace industry is dominated by South African Airways, the commercial carrier and South African Airways Technical – the maintenance and repair division.

South Africa's Aerospace and defence contractors cover a wide but shallow technological base. Shallow refers to the fact that the industry is currently supplying sub-systems and not producing sufficient Tier 1 niche applications like UAV's (Unmanned Aerial Vehicles – expertise developed by Kentron), missiles and satellites.

This is both its strength but also its weakness. It has developed expertise in the areas of:

- Ultra-mobile heavy and armoured wheeled vehicles
- Transponder
- Parachutes
- Low cost simulators
- Combat helicopters
- Composite materials and composite rotor blades for helicopters
- Radar
- Unmanned Aerial vehicles (UAV)
- Fibre optics
- Lasers
- Fuse technology
- Electronic warfare (Army, Air Force and Navy)
- Flat screen technology
- Secure communications
- Avionics, land and maritime electronics, including Fire Control, System and Integrated Command, Control and Intelligence systems, etc
- Single crystal turbine blades for aircraft engines
- Refurbishing and upgrading of redundant equipment
- Integration of complex materials and systems at various engineering system levels
- High speed advanced gearboxes and transmission systems

8.2.4 Strengths of the Industry

The following sets out the strengths of the South African Aerospace industry:

- Capability
- Flexible and innovative due to historical reasons
- In some parts of the industry, short development cycles are achieved (avionics)
- Good quality in parts of the industry
  - Skills base
- Niche expertise limited to certain disciplines
- Medium to low labour rates
- Flexible and innovative workforce

8.2.5 Weaknesses of the Industry

The following sets out the weaknesses of the South African Aerospace industry:

- Capability
- Limited, obsolete and aging facilities
  - Contracts
- Contracts are still heavily weighted towards military needs
- Small in size and volume but across the tiers
- Lower tiers have very few critical customers upon which they are reliant
  - Skills base
- Niche expertise resident in retired or close to retirement aged personnel
- Niche expertise limited to certain disciplines
- Experienced engineering and other personnel are leaving the industry and the country
- Very few graduates in Aerospace and aeronautical engineering

8.2.6 Opportunities in the Industry

- The Aerospace industry is characterised by long cycles: if the correct decisions are made now, they will pay off in 20 years time
- The Aerospace market is forecast to grow by at least 25% in real terms over the next 20 years ro $250 billion per annum
- Towards the end of this 20 year period, we can expect to see the appearance of highly innovative new products, such as autonomous air combat systems and very quite eco-friendly civil aircraft, all integrated within a single air traffic management system
- Has all the characteristics of a global industry
- Significant skills development and technology transfer in terms of offset programmes

(Development of a National Aerospace Strategy – DTI)

8.2.7 Challenges for the Industry

- Negative public perception of Aerospace as a defence driven industry, fuelled by negative publicity of procurement process
- Creating a “Team SA”
- Not a large local market – need access to international markets
- Africa as opportunity
- It is a very R & D and innovative industry

(Development of a National Aerospace Strategy – DTI)**Global Technology Trends**

Compliance with increasingly stringent international and domestic environmental regulations is one of the major challenges facing the firms involved in aircraft engine manufacturing as well as the small and medium-sized enterprises involved in the supply of metal surface finishing services.

These environmental regulatory pressures and the cost of compliance are expected to become even more severe within the next decade as the public's desire for a cleaner environment and improved workplace safety become more pronounced. In particular, the level of engine emissions, engine noise and the use of toxic chemicals in metal finishing processes will become prime targets for severe controls by environmental agencies. Consequently, these firms must pursue advancements and innovative solutions in response to these environmental regulations, while remaining competitive within international Aerospace markets.

The regulatory environment and the customer dictate trends to a large degree.

8.3.1 Regulatory environment

The regulatory environment refers to all external influences imposed by regulatory agencies on the manufacture and operation of an aircraft. Technologies are required that will

- Reduce external noise, as measured on the ground during takeoff, flyover and landing
- Reduce emissions from engine exhaust, crankcases, transmission housings and fuel tanks
- Reduce or eliminate the use of hazardous materials in manufacturing, repair and maintenance
- Eliminate manufacturing processes that use or produce toxic waste products
- Improve flight safety by providing more accurate navigation systems and better pilot warning systems for ground proximity, wind shear, clear air turbulence, and avoidance of mid-air and ground taxi collision
- Reduce flammability of cabins and other structures
- Improve
  - structure weight
  - engine weight
  - fuel efficiency
  - landing gear weight
  - systems weight

8.3.2 Customer

- The customer varies, depending on the level at which a firm operates in the supply chain.
- " Higher, faster, farther" replaced by "Safer, quieter, cleaner, cheaper"
- Cheaper
  - Design cycle time
  - Manufacturing cycle time
  - Recurring costs
  - Fuel efficiency
- Comfort
  - Cabin noise and vibration

– Entertainment

8.4 Selection of Research Countries

This section gives some background on why specific countries were selected as international benchmarks.

8.4.1 United States of America

Aerospace and aviation are important assets for the US. Apart from providing national security benefits, the Aerospace industry makes a critical contribution to American economic growth and standard of living.

It is estimated that in 2000 the US Aerospace industry contributed $900 billion to the economy, which translated to roughly 9% of total US GDP. The sector boasts some 11 million jobs.

The United States has been a world leader in space activities throughout the Space Age. With the demise of the Soviet Union and the subsequent steep decline in space spending in Russia, both civil and military, the U.S. today stands as the single space superpower

Interestingly, though, the US is losing it's supremacy as leader of the Aerospace market. In 1985, the US controlled more than 73% of the commercial aircraft market – today, this control is less than 50% of the global market.

As a result, the Aeronautics Research and Development Revitalisation Act of 2003, S.309, was gazetted as a broad range agenda to reinvigorate America's aeronautics and aviation R & D enterprise and maintain America's competitive leadership in aviation. This resurgence might prove useful when contextualising South Africa's role in the Aerospace industry.

8.4.2 Brazil

It is estimated that the Brazilian Aerospace industry started about twenty years ago , and growth was spurred from the recognition of a national need to use aircraft for regional transportation and to patrol its long coastline.

In absolute terms, Brazil's Aerospace industry is relatively small, but Brazil considers aviation and Aerospace industrial development to be a vital sector for national development and defence. Air transportation is a critical link in Brazil's infrastructure both for economic growth and military defence.

Embracer is one of the few companies outside of the US and EU with a successful position in the global Aerospace market, exporting to every continent worldwide. It produces regional aircraft (has about 10% of the world regional aircraft market) and is also involved in a number of military Aerospace co-operations. Brazil also constructs rockets and satellites.

8.5 Technology Identification

The table below represents the leading technologies identified by the various countries' experts as imperative for the sustainability of the Aerospace sector. The technologies identified will prove to be critical in the quest to create Aerospace products that will meet cost, performance, safety and comfort expectations of operators and their passengers.

Table 25:Technology identification

Technology description	US	Brazil	SA
Composite Materials Advanced composites have emerged as the structural materials of choice because of their superior specific strength and stiffness properties Benefits significantly lower operating and manufacturing costs, increased flight safety, and markedly reduced structural weight in Aerospace vehicles Applied to major components the weight saving which could potentially be more than 20%, would have a marked effect on aircraft fuel burn, resulting in lower operating costs in addition to the environmental benefit from using less fuel per passenger-mile flown		Important	Important
Hypersonic aero-thermodynamics Advanced computational fluid dynamics comprises the key enabling technologies for aerodynamic design and optimisation. They hold exceptional promise for improving aircraft performance and reducing the design cycle time for wings, high lift systems and engine installations. In terms of engines – future gas turbine engines will need refined aerodynamic design and optimisation to achieve substantial improvements in engine efficiency, noise reduction and development costs. Advanced computational fluid dynamic tools are crucial for designing fuel-efficient gas turbine engines		Important	Important
Sensors These sensors are used in both developmental, testing,	Important		Important

and routine health monitoring applications for engines, airframes, and subsystems			
Security (passenger and baggage screening) Likely security upgrades range from: Baggage scanning equipment, physical security of ground-based Air Traffic Control and monitoring equipment in remote areas; perimeter surveillance systems, to CCTV and access control systems	Important		
Health and Usage Monitoring Systems Monitor process parameters such as engine temperature, oil temperature, oil pressure and chip detection. Provides a health status and enables monitoring of the flight system. Aim is to reduce downtime by having parts in place before their end of life	Important		Important
Air traffic controls The integration of satellite based data to reduce cost and reduce efficiency.	Important		
Aircraft Noise Abatement Compliance with environmental legislation, especially in the EU and general reduction of aircraft emissions	Important		Important
Manufacturing processes "Leaner and meaner", low waste, low scrap and ability to reconfigure machinery to tool different parts			Important

It is interesting to note how differently the US expert viewed what were important technologies in the Aerospace sector. 9/11 obviously plays an important role in their current thinking; hence air traffic control and passenger and baggage screening assuming the high level of importance.

The table concludes that the following technologies are important for the South African context:

- Development of composite materials
- Hyper aero-thermodynamics

- Sensors
- Health and Usage monitoring systems
- Aircraft noise abatement
- Leaner manufacturing processes

8.6 Description of Technologies

8.6.1 Development of composite materials

The use of advanced materials and structural technologies is important throughout the sector. New materials must be characterised, and effective means of incorporating them into practical products must be devised as they emerge. New structural concepts must continuously be conceived and evaluated. Coating technologies will be relied upon to deliver more versatile and durable structures under the constraints of cost and ever-tightening environmental requirements. Increasing use will be made of advanced composite and hybrid materials in order to take advantage of potentially large weight reductions, enhanced corrosion resistance and improved productibility. Smart structures will emerge in applications requiring their adaptability and where no other known technology can give comparable performance. Similarly, energy-absorbing structural technologies will be essential in meeting anticipated new, more stringent regulatory and performance requirements. New metallic materials will offer incremental performance improvements over current metals. The following specific technologies will be described further:

Coatings and Surface Modification Treatments

Coatings and surface modification technologies will play an extremely important role in coming years. For the original equipment manufacturer, they offer a method of increasing efficiencies and improving structural integrity. They allow repair and overhaul contractors to offer their customers a repaired product that would be comparable in performance to a new part, for a fraction of the cost of a new part. For the aircraft operator, coatings will provide a direct cost-benefit from reduced spares requirements and a lower rate of in-flight incidents.

Composite and Hybrid Structures

This critical technology offers reduced structural weight (by 20 30 percent) through density reduction and higher permitted operating stress. For composites, a smoother external finish can yield lower drag and a more attractive appearance. Process improvements are expected to yield reduced manufacturing costs through parts count reduction and, for fibre metal laminates, the elimination of doublers. Significant improvements in product durability can be expected through improved fatigue resistance, resistance to impact damage in the case of fibre metal laminates, and improved resistance and/or tolerance to corrosion. Finally, fibre metal laminates can be exploited for fire and bomb containment, exploiting the capability of certain composites to endure elevated temperatures, avoiding the use of expensive, heavy stainless steel or titanium.

Smart Structures

The advantage of smart structures over more conventional structures is that they can adapt to their environment as the conditions around them change. Of the different smart structure technologies undergoing development, shape control, vibration control, loads alleviation, and loads and health monitoring are considered the most promising for aeronautical applications

Energy-absorbing Structures

Regulatory requirements for crash survival, engine burst containment and bird strikes must be met. Strictness of these regulations and product liability concerns will increase in the near future. Also, vibration in fixed-wing aircraft and helicopters is a problem for crew and passengers, and can lead to shortened service life for structural components and system components. One method of solving these problems is energy-absorbing materials. A fundamental, competitive reality is the need to produce light- weight structures, while meeting energy-absorbing requirements.

Metallic Materials

New metallic materials offer, at a minimum, incremental improvements over conventional alloys in material properties such as strength, density, corrosion resistance, resistance to stress corrosion cracking, fracture toughness, elevated temperature resistance, weldability, formability, etc. This critical technology is comprised of three general categories of metallic materials: lightweight alloys; high-strength structural alloys; and high-temperature alloys

8.6.2 Hyper Aero-thermodynamics

The above falls into the category of multidisciplinary design and optimisation, which describes an integrated set of computer programs that correctly size and optimize the structural design of aircraft or engines to meet design requirements, while constrained by factors such as weight, cost, material properties and vibration or flutter considerations. The preliminary definitions of structure, systems and loads will become available for detailed design much earlier, substantially reducing design cycle time and also facilitating working with partners.

Future gas turbine engines will need refined aerodynamic design and optimization to achieve the substantial improvements in engine efficiency, noise reduction, development costs and operating costs required by the customers. Advanced computational fluid dynamics tools are crucial for designing fuel-efficient gas turbine engines.

Advanced computational fluid dynamics methods, including faster Navier-Stokes codes, adaptive gridding and rapid inverse design, comprise the key enabling technologies for aerodynamic design and optimization. They hold exceptional promise for improving aircraft performance and reducing the design cycle time for wings, high lift systems and engine installations. Methods based on three-dimensional Navier Stokes computations with adaptive gridding are expected to be in general use for design and analysis

8.6.3 Sensors

Sensors provide information about conditions such as air temperature, air pressure, speed and vibration. Working together, sensors and microprocessors provide many novel applications.

In the hypersonic realm, sensors are used to monitor critical parameters that could give early warning of defects in the aircraft structure. It can also provide useful data for preventative maintenance.

8.6.4 Health and Usage Monitoring systems

The integration of health monitoring systems to monitor, to assess, and eventually to re-configure flight systems automatically will reduce crew workload and aircraft downtime, while providing an increased margin of passenger safety and comfort.

8.6.5 Aircraft Noise abatement

Development of Lower engine Noise Technology

The potentially viable noise abatement technologies considered for investigation include innovative design concepts for quieter engine fans and compressors using computational fluid dynamics codes and computer aeroacoustics calculations for better prediction of flow interaction and acoustic propagation phenomena. Efficient attenuation liners, engine inlet/propeller interaction, efficient forced mixer nozzles and active noise control technologies should also be considered for investigation.

Aircraft Emissions Reduction

Critical technologies considered for investigation and development in the reduction of nitrogen oxide (NOx) compounds, carbon monoxide (CO) and volatile organic compounds (VOCs) and smoke from engine emissions include: advanced combustor wall cooling through the use of advanced materials or new cooling techniques; expanded use of computational fluid dynamics codes for modelling pollutant formation chemistry; weak extinction performance and combustion instability to enable accurate prediction of the formation of NOx, CO and VOCs; improved fuel mixing designs to ensure good air-fuel mixing in the combustors; and multi-stage combustor concepts, which have very good potential for low emissions but may result in increased costs. To achieve these objectives, supporting technologies such as advanced combustion technologies test facilities and precision manufacturing capability will be necessary.

8.6.6 Manufacturing Processes

Improved manufacturing capabilities are essential to the industry's success in producing superior products that will meet the cost, quality and performance expectations of their customers.

The single, most important consideration in maintaining global competitiveness is the requirement to be able to generate, transmit and utilize technical data by an effective, common methodology (OEM to supplier, designer to machine). All aspects of the process design, analysis, process modelling, process planning/programming, process monitoring, process control/ real-time feedback and inspection must be based on a common, three-dimensional definition that not only will maintain design integrity, but also will eliminate many wasteful reprogramming steps.

In addition, South African companies that specialize in certain processes (such as composites, ceramics, castings, forgings, specialty coatings, etc.) have capabilities that, if strengthened through the development and introduction of technologies specific to their speciality, could increase the South African share of world markets for these types of manufacturing.

High Velocity Machining

To remain competitive, airframe manufacturers have set new component/part design and manufacturing goals for themselves and for their suppliers: weight reductions of 15-20 percent; cycle time reductions of 25 percent; cost reductions of 20-30 percent; and direct operating cost reductions of 10-15 percent. High velocity machining provides significant and unique capabilities in all of these areas. To optimize these benefits, advances are required in tool design and machine tool structural design to minimize vibration, in the lubrication/cooling system to control heat production, in increased spindle/bearing life, and in improved ability to machine "hard" (i.e.: high-strength steel) materials.

Joining all materials

Newer materials are being used, or contemplated to use, in aircraft structures that are significantly more difficult to join than traditional material.

8.7 Conclusion

Taking all of the above into consideration, the matrix below represents a summary of the technologies identified as important and that should be taken into consideration for further development

Table 26: Technology positioning analysis

Technology	Technology requirements	South Africa's position to take advantage of the requirements
Development of composite materials	Increased use of aluminium and magnesium Fundamental understanding of the physical and structural properties of light metals Access to enabling technologies R & D to ensure improved metal quality Availability of relevant education & training to ensure a well-trained workforce	SA has well developed aluminium industry and has available raw material resources. SA is also rich in materials like aluminium, magnesium, plastics, titanium and hybrid materials like foamed materials. LMDC at CSIR The Government can take advantage because industry development will include the development of market opportunities through local and international investment and technology transfers to enhance the establishment of new enterprises in the industry There is also the possibility of identification and exploitation of opportunities for black economic empowerment and SME's
Development of hypersonic thermodynamics	Necessary for hyper sonic aircraft Access to enabling technologies	Position to take advantage is quite low because it is a Niche expertise – refer Philip Haupt at CSIR, but SA is not sufficient to become a global player. It Will affect any Tier 1 design work that South Africa may do so the impact of the technology is quite high. Government can take advantage. The Government can take advantage because industry development will include the development of market opportunities through local and international investment and technology transfers to enhance the establishment of new enterprises in the industry There is also the possibility of identification and exploitation of opportunities for black economic

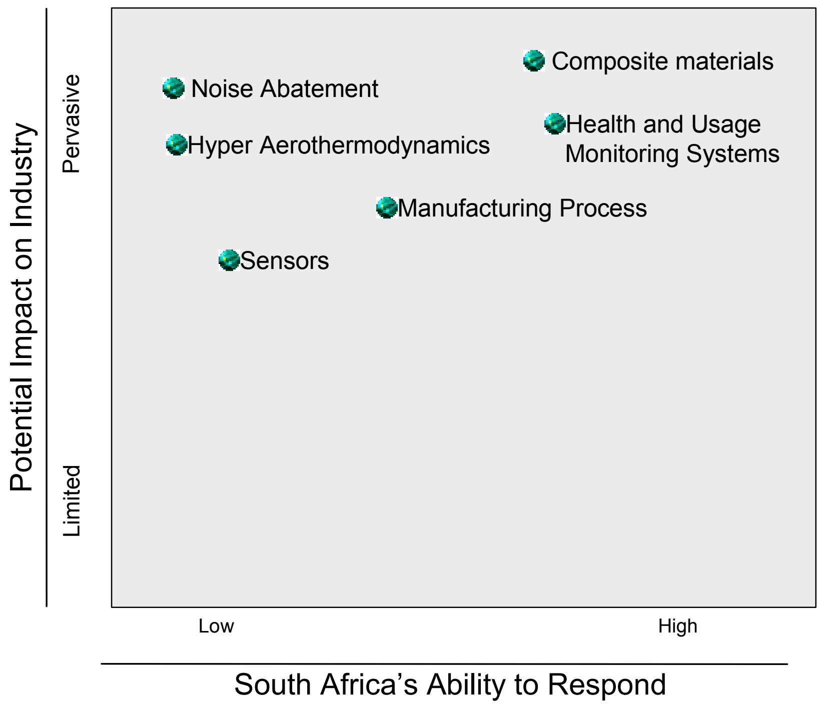
Technology	**Technology requirements**	**South Africa's position to take advantage of the requirements**
		empowerment and SME's
Health and Usage monitoring systems	SA is a player already. AMS is installing HUM system on BAE Hawk	Player already. Can only have impact if the industry is to sustain current market share and grow this. Technology funding and assistance with marketing. What happens when the current contracts run out? The Government can take advantage because industry development will include the development of market opportunities through local and international investment and technology transfers to enhance the establishment of new enterprises in the industry There is also the possibility of identification and exploitation of opportunities for black economic empowerment and SME's
Sensors	Fundamental research area in development of sensors. SA can apply sensors developed elsewhere in products as we do today. Huge investment needed in fundamental research e.g. nanotechnology and MEMS	Value added development of products using sensors and integration of these into commercial off-the-shelf solutions. Some of the players in this area are ATE, Denel Aerospace and Denel Optronics, M & Mtek and Defencetek. SA has strengths in avionics development. This is demonstrated by the export sales of these companies. R2m invested by Armscor for the application of MEMS sensors in navigation equipment – Denel Optronics technology programme. Good base in application of technology Support for the high technology industry produces spin-off for the training and development of personnel as well as opportunities for the application of this technology in other areas e.g. LaserM now exporting – is a spin-off from defence industry. The Government can take advantage because industry development will include the development of market opportunities through local and international investment and technology transfers to enhance the establishment

Technology	Technology requirements	South Africa's position to take advantage of the requirements
		of new enterprises in the industry There is also the possibility of identification and exploitation of opportunities for black economic empowerment and SME's
Noise Abatement	Expert knowledge R & D investment	SA has some niche expertise in this area. A big impact in terms of complying with EU regulations, for example on noise and emission reduction. The Government can take advantage because industry development will include the development of market opportunities through local and international investment and technology transfers to enhance the establishment of new enterprises in the industry There is also the possibility of identification and exploitation of opportunities for black economic empowerment and SME's
Manufacturing processes	Upgrade of existing manufacturing facilities. Improved machining capabilities	Manufacturing facilities are not modern Manufacturing "culture" in SA Aerospace is not lean and mean. But there is a big impact in terms of South Africa because of an aging manufacturing set-up. The Government can take advantage because industry development will include the development of market opportunities through local and international investment and technology transfers to enhance the establishment of new enterprises in the industry There is also the possibility of identification and exploitation of opportunities for black economic empowerment and SME's

8.8 Conclusions and Recommendations for Sector Development

In light of the previous table, the following grid positions the identified technologies in relation to its relative impact and South Africa's position in terms of technology requirements.

Figure 15: Impact analysis grid



The grid highlights quite clearly that the South African Aerospace industry, taking cognisance of its strengths and dominant position, should concentrate on retaining its competitive advantage in Health and Usage Monitoring systems and should develop a capability in composite materials. In terms of hyper aero-thermodynamics, noise abatement and sensors, there exist pockets of expertise locally and because of the relative impact of these two technologies; it is recommended that these technologies be pursued further.

South Africa should pay special attention to improving its manufacturing capabilities in terms of catching up with other global players. In terms of going forward, cognisance must be taken of the technologies that were identified in the automotive industry study. There exists cross sectoral impact and a complimentary relationship between these two sectors.

8.9 Technology Support for Sector Development

This section looks at programmes, support mechanisms and policies introduced by government to boost the Aerospace industries in the United States and Brazil, respectively. It also serves as detail and a way forward for decision makers locally in terms of repositioning the Aerospace industry in South Africa for the future.

8.9.1 The United States of America

Historically NASA has been the primary agency for Government support for Aerospace

- The NASA budget of about $15 billion is approved every year by Congress, but the amount allocated to aeronautics has been declining over the last several years. Less than $1 billion is currently aimed at aeronautics, with emphasis on projects that are at the lowest level of development (i.e. basic research rather than development)

- As projects move from basis research to the prototyping stage, they are generally expected to become the responsibility of industry

- There is a strong political feeling in the US that if the developments will benefit industry, then industry should pay for it

- NASA is considered to be effective in demonstrating new technology, but much less so in moving technology o the development stage – this tends to be done more inside companies who then want to keep the technology in-house

- In 2002 NASA and the Federal Aviation Administration (FAA) asked the National Research Council to establish the Committee on Aeronautics Research and technology for Vision 2050
  - To assess the visions and goals for US civil aviation
  - To assess technology goals for the year 2050
  - Key aspects include improved passenger comfort, convenience, cost and the societal impact (non-renewable fuel use, emissions, noise, etc); specific technological areas identified as being of particular interest include
    - Human integrated systems
    - Autonomous and interactive technologies
    - Noise and emissions
    - Wake vortices

- Situational awareness
- Systems-engineering methods
- Avionics
- Composite materials
- Low emissions combustor technology
- Nanotechnology
- High temperature engine materials

No single organisation is currently responsible for developing a comprehensive solution to these problems, and the Committee considers that such an agency is required. NASA is responsible for long range R&D. FAA is responsible for traffic management and carrier regulation. In addition to NASA, three other agencies could make investment in technology in this area, but in each case it is either fundamental, early stage research, or it meets some immediate governmental needs (e.g. ATC, or increased security)

- Department of Transportation
- Department of Defence
- FAA

The Defence Advanced research Projects Agency (DARPA) is the central research and development organisation of the Department of Defence that manages and directs basic and applied research and development projects for the DOD. For example, one of the areas is the Joint Unmanned combat Air Systems Programme.

The National Research Council (NRC) is part of the National Academies, which are private, not-for-profit institutions providing science, technology and health policy advice under a congressional charter. NRC assembles a panel of industrial/academic experts to advice on areas of science and technology

If NASA identifies a need for research into a developing technology, it invites universities and research organisations to submit proposals. Often it appoints one of its three own research laboratories to do the work. There is some feeling that this approach does not always result with the best teams, and there have been attempts to encourage more government/private consortiums, although the results have been only mixed.

8.9.2 Brazil

The Sao Paulo State Technology Cluster comprises of a cluster of aeronautical and Aerospace industries, with representation by the leading players. The Aerospace technology development and R & D are divided between two Governmental Ministries, the Ministry of Defence is responsible for aeronautic programmes (which includes airplanes, launchers, rockets, etc) while the Ministry of Science and Technology is responsible for space programmes (satellites and satellite technology/applications), within which AEB (the Brazilian Space Agency) is responsible for overall coordination of programmes and for updating Brazil's National Programme for Space Activities

Although AEB is part of the Ministry of Science and Technology, it is considered to be independent from the Ministry, and impartial in terms of providing funding for the programmes that fall under the Ministry of Defence. The AEB proposes policies, long term planning, supervision of activities, etc.

However, not all funding of Aerospace activities is coordinated by AEB – each Ministry has some additional funding (from their budget) and they also obtain funding from Foundations, Industry, the sale of services and products (e.g. launching satellites, mapping and other data).

AEB supports research studies to analyse technical, economic, political and commercial issues related to Aerospace in order to support decision-making processes in the space arena. The AEB also develops a report based on interviews in the technology, science and business communities to select a "list of technological topics" that are considered essential to national development in the next 5 to 20 years

This same organisation is responsible for coordination of the Aerospace research activities undertaken by INPE (National Space Research Institute) within the Ministry of Science and Technology and by DEPED (Research and Development Department of the Aeronautical Command) within the Ministry of Defence. It is part of the Ministry of Science and Technology, but also responsible for allocating funds and projects to the Ministry of Defence, therefore putting AEB in a "difficult" position, as a result, changes in the organisation are expected to take place soon.

- R & D organisations within the two Ministries work with private industry as well as with Universities
  - Work and budgets are generally coordinated by AEB
- The main organisation within the Ministry of Defence is the CTA (Aerospace Technical Centre), which focuses mainly on Defence, and which works mainly in the development of rockets and airplanes?

There are several organisations within CTA, but the main ones are:

- IEA (Advanced Studies Institute) performing basic research
- IAE (Aeronautics and Space Institute) focussed on development and
- ITA (Aeronautic Technology Institute) which is responsible for academic type research and training

The main organisation within the Ministry of Science and Technology is INPE, which is focused on satellite technology and its commercial applications, including capturing and selling satellite images. This programme falls under the Ministry of Science and Technology's CNPq (National Council for Scientific and Technological Development) that funds R & D projects with an aim of increasing Brazil's competitiveness

Funds are applied to research in 14 specific fields (petroleum, infrastructure, transportation, et.) and each field has different sources of funds. According to sources interviewed, funds have been plentiful, for example, in the petroleum industry, and reportedly at least 22 000 of the over 30 000 PhD's active in Brazil were trained with support of the CNPq

In terms of the Aerospace sector, FINEPE is in a phase of "collecting" money (a percentage of royalties paid overseas for technical assistance and royalties)

Money will be spent through Universities and Research Institution; decisions are made by a Committee conformed by Government and Industry representatives (Embraer) that selects the projects to be funded. Additional support is received for Aerospace R & D from State (mainly the State of Sao Paulo) programmes. The state of Sao Paul's support comes through the Incentive Programme for Space Science and Technology

8.9.3 South Africa

There are currently no formalised policies or support mechanisms in place with regard to the South African Aerospace industry. ASSEGAI was the first formal position paper put together.

METALS AND MINERALS SECTOR

9 TECHNOLOGY DEVELOPMENT TRENDS OF THE METALS AND MINERALS SECTOR

9.1 Context of Metals and Minerals Industry

9.1.1 Working Definition of Metals and Minerals Industry

The seven principal classes of metals and minerals are:

- Base metals e.g. steel, copper, lead or zinc
- Ferrous metals e.g. these are metals containing iron
- Precious metals e.g. gold, silver and platinum
- Minor metals e.g. indium, silicone
- Energy minerals e.g. oil, gas and coal
- Construction minerals e.g. cement, concrete and masonry
- Diamonds & precious gems
- Global Metals and Minerals Industry

The Metals and Minerals industry is relatively small with the top 150 listed international mineral companies having a combined market capitalisation of US$320 billion at the end of 1999. This global total is lower than a number of individual companies' market capitalisation at the same time i.e. General Electric and Exxon Mobil.

The industry is fairly fragmented and there exists a lack of linkages along the chain of production, from exploration through to mining, metal production, fabrication and recycling.

The structure of the Metals and Minerals Industry is complicated and diverse. Some minerals and metals are produced mainly by large mining companies, while others may be produced primarily by small ones.

The world's largest mining and metals companies are, in order:

Table 27: Worlds largest mining and metals company

Name of company	Country	Main business
Alcoa	United States	Aluminium
Nippon Steel	Japan	Carbon and stainless steel
Anglo American	UK	Coal, steel, forest production, diamonds, gold
BHP Billiton	Australia, UK	Coal, steel, oil and gas, ferroalloys

9.2 South African Metals and Minerals Industry

The industry's contribution to the GDP of South Africa represents 12.3 % of the total manufacturing GDP, and this translates to 3.99 % of the total economy (2002 figures). Year on year growth for this industry is relatively high at 12.3 % (2002).

Industry imports were an amount of R 48,705,012 and their exports R 50,648,028. This led to a trade balance deficit of R 1,943,016 (R '000) (2002 figures).

The technology dependency of this industry is high, but its self-sufficiency is relatively low.

South Africa has a third or more of the world's reserves of alumino-silicates, chromium, gold, manganese, platinum-group metals, titanium and zirconium. This exceptionally large reserve base allows South Africa to play an important role in the world in respect of the production and exports of many primary metals. South Africa's metal industry has made an important contribution to the national economy, and has thereby provided considerable impetus for the development of an extensive and efficient physical infrastructure and thereby also contributed to the establishment of the domestic manufacturing sector. The metal industry is a well-established and resourceful sector of the economy and possesses a high degree of technical expertise and is able to mobilise capital for new development. It has a reputation worldwide as a leading and reliable supplier of a large variety of metals.

During 1998, some 466 107 workers were employed in the mining industry, representing about 4 per cent of the country's total economically active population. The gold mining sector was the largest employer, with 55,5 per cent of the total employees, followed by the platinum-group metals industry with 19,3 per cent. The industry has shed some 331 180 jobs over the last 10 years, largely as a result of a decline in gold production (annual output fell from 607,7 tons in 1989 to 464,2 tons in 1998), but also due to rationalisations and restructuring in the industry as a whole.

There are two distinct groupings within the South African metals sector:

Firstly, there is a very mature metals sector, which includes the heavy metals and to some extent the precious metals

- This sector has low growth in the levels of demand but South Africa does have significant competitive advantage in this sector
- The focus in this sector is currently on improving efficiencies and lower costs
- Moving towards consolidation

Secondly there is a developing metals sector, which includes the light metals sector with metals such as aluminium, zinc, magnesium and titanium

- This sector has enormous growth potential but the current costs associated with obtaining these metals make large scale production an extremely capital intensive process
- The focus in this sector is on developing a continuous process of extracting these metals as to lower the costs of production.

One of the challenges facing the metals sector in general is the high level of raw material export

- South Africa is traditionally known for its mining and extraction capabilities
- The raw material is however exported to other countries for further value added initiatives and then imported back into South African at significantly higher costs
- A number of initiatives are currently being undertaken to improve the competitiveness of the down stream metals fabrication in South Africa

The Witwatersrand gold field is by far the biggest known resource of gold on earth and despite having produced over 45 000 t of gold (40 % of all the gold reckoned to have been produced by mankind since 4000 BC), it has been estimated that the gold field still contains as much as 40 % of known global gold resources.

South Africa also hosts over 80% of the world's **manganese** reserves, most of this occurring in the Kalahari manganese field.

South Africa dominates the world production of aluminium silicates, particularly andalusite. South Africa, host more than two-thirds of the world's known chromite reserves and mined virtually a half of the world's chrome ore in 1998.

Though South Africa is the world's second largest producer of heavy mineral sands after Australia, it has a marginally larger reserve base (estimated at 30% of the world's known reserves) and is thus a good exploration target.

South Africa is currently the world's 8th largest producer and 6th largest exporter of iron ore and has an estimated reserve base of 6 billion t, which together with low electricity tariffs and a good infrastructure, offers development opportunities.

South Africa's Northern Cape Province contains 12 000 Mt or 80% of the world's high grade, land-based manganese reserves and thus has significant potential for exploration, joint ventures and further development.

South Africa's PGM production has grown at 4.4% per annum over the last decade, with platinum accounting for 57.5% of this and palladium 26.6%.World demand for PGM's appears set to continue growing, creating the potential for further production.

In 2000 the International Iron and Steel Institute (IISI) ranked South Africa as the 21st largest steel producing country in the world and 8th as a net exporting country of primary steel. The largest steel producing country in Africa, producing 62% of the total steel crude production on the continent during this year, South Africa's total crude steel production amounted to 8,6 million tons in 2000. The local market consumed 57% and 43% was exported.

South Africa's non-ferrous metal industries comprise aluminium and other metals, including copper, brass, lead, zinc and tin. Aluminium is the largest sector. SA is ranked 8th in world production of aluminium. SA produces approximately 677 kt of primary aluminium per year - 512 kt of it is exported.

Non-ferrous metals sales are estimated at R3 billion per annum, excluding aluminium but including primary copper, primary zinc and the secondary copper, zinc, tin and lead industries.

South Africa's primary stainless steel production capacity is in the order of 500 000 tons per annum, but presently only 150 000 tons are converted locally into value-added products. Holding over 50% of the world market, South Africa is the leading world designer and producer of tank containers.

The jewellery industry, including gold, platinum and silver, employs approximately 4500 people while the diamond industry employs approximately 2500.

9.2.1 South Africa's Competitive Advantages in the Metals and Minerals Sector

Raw materials

South Africa is internationally renowned for an abundance of mineral resources, which accounts for a significant portion of both world production and reserves. Some of the more important minerals include:

Table 28: Important minerals

Mineral	Unit	Reserves	World Rank	Production	World Rank
Chromium	Million tons	5500	1	6.662	1
Vanadium	Thousand tons	1200	1	18	1
Platinum					
Group metals	Unit	62,816	1	207	1
Manganese	Million tons	4000	1	3.635	1
Titanium	Million tons	146	2	1.057	2
Zinc	Thousand tons	15,000	5	63	18

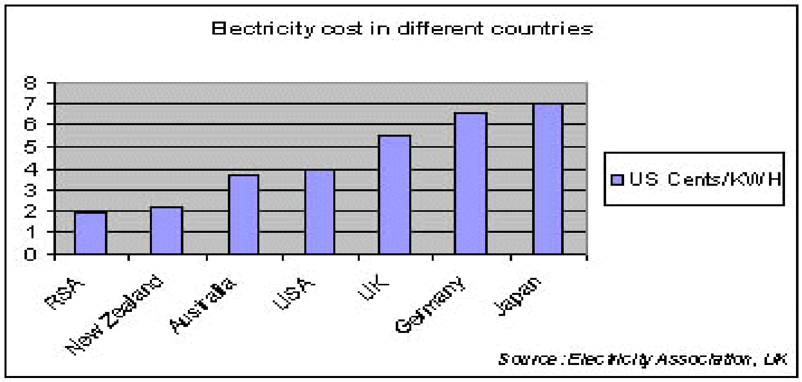
A host of large-scale mineral-beneficiation projects are aimed at exploiting the potential of South African natural resources. South Africa have world-scale primary processing facilities covering carbon steel, stainless steel and aluminium industries in addition to gold and platinum.

A wide range of materials is available for jewellery, including gold, platinum, diamonds, tiger's eye, and a wide variety of other semi-precious stones.

Availability of world's cheapest electricity

Electric power, largely generated by Eskom, the country's electricity utility, is amongst the cheapest available anywhere in the world. This low electricity cost has been instrumental in the establishment of sizeable ferroalloy, stainless steel and aluminium beneficiation industries.

Figure 16: Electricity costs selected countries



Finance

Through partnership with a state-financing organisation, the Industrial Development Corporation of South Africa (IDC), companies can access loans or equity at preferential rates.

Trade Preferences

South Africa has entered into preferential agreements with the US, EU and sub-Saharan countries. These agreements confer generous trade benefits as outlined below.

The Generalised System of Preference (GSP)

GSP is extended to South Africa by 25 countries, allowing South African exporters to gain preferential access to their markets.

9.2.2 Major foreign companies operating in the sector in South Africa

Recognising South Africa's many advantages, several international companies have established major operations in South Africa. Some of the more prominent ones are listed below:

Table 29: Activities of companies

Company	**Country of Origin**	**Activities**
Billiton SA Ltd	UK	Aluminium smelter
Pohang Iron and Steel	South Korea	Ferrochrome smelter
Acerinox	Spain	Stainless steel
Oro-Africa	Italy	Manufacture of gold and diamond chains, rings, bracelets
Silmar Spa	Italy	Manufacture of gold chains
Oro-Maska	India	Manufacture of gold chains, bracelets, rings and diamond pendants, chains
South Africa Royal Manufacturers	Canada	Manufacture of gold chains, rings, bracelets

9.2.3 Strengths of the South African Metals and Minerals Industry

- South Africa's supply of raw materials
- The high level of advancement in the mining sector
- South African culture of innovation
- Pockets of excellence in mining capital goods and deep mining technology
- A very strong iron and steel industry
- The Advanced Metals Initiative is a newly established government initiative which is positive for the local metals industry
- South Africa produces in excess of 60% of the world's platinum group metals including platinum, rhodium and palladium, which are essential catalysts in the converter.

- South Africa is home to over 70% of the world's chromium, an essential ingredient in the stainless steel used to house the catalyst and produce modern auto exhausts.
- South Africa also produces in excess of 50% of the world's ferrochrome and has prompted the development of Columbus Steel. Columbus currently supplies in excess of 30 000 tonnes of stainless steel per annum to the South African automotive exhaust industry for export around the world.
- Access to the Southern hemisphere. Transport costs are distance related and there will be some markets that are closer to South Africa.

9.2.4 Weaknesses in the South African Metals and Minerals Industry

- At present R&D in advanced materials in South Africa is limited
- Lack of infrastructure
- Lack of appropriately skilled people
- Insufficient focus in areas of R&D
- Lack of modern equipment for R&D
- Lack of networking
- Lack of market information
- Small player in global terms
- SA's distance from and sales markets (exports)
- Inefficiencies within the transport sector (road, rail, and air)
- Difficulty in meeting the human resource requirements required by the industry

9.2.5 Opportunities in the South African Metals and Minerals Industry

- Steel: Downstream beneficiation in terms of automotive parts, car bodies, pipes, tubes, structural steel products, furniture
- Stainless Steel: Rolling Mill, pipes and tubes, building materials, catalytic converters, exhaust manifolds, refrigerators, microwave shells, furniture

- Aluminium: Primary smelter, building products, windows and frames, patio doors, extrusions, conductors and rods, vehicle bodies and flooring, engines, cylinder blocks, pistons, alloy wheels, high-pressure die-casting, packaging foil, industrial flooring

- Jewellery: Export of 9ct, 14ct and 18ct jewellery to Europe and the USA, encompassing ethnic and western designs. Diamonds, loose, cut and polished and set in jewellery and a host of platinum items

- Capital Equipment: Machine tool manufacturing and petrochemical equipment

9.2.6 Threats or barriers to the South African Metals and Minerals Industry

- HIV/Aids – constitutes an unquantifiable threat at this point in time

- Local raw material pricing is dependent on foreign exchange rates

- Local skills base may not be suitably competitive

- Perception of foreign investor friendliness

- Perception of Africa

- Internationally registered patents

- Effect of China's predicted change in the market from a major importer of heavy metals to a major exporter in the medium terms

- Consolidation of the steel industry should happen in the foreseeable future

9.3 Global Technology Trends

The metals and minerals sector is mature world wide with little major innovation taking place. The current technology trends are towards incremental improvements in the various value chain processes. The purpose of innovation, especially in the heavy metals sector, is to ensure business sustainability within the commoditised market and emphasis is placed on aspects such as the improved use of gravel as a form of ore, the improved extraction of lower grade ore by developing improved reduction and extraction techniques and the more efficient use of energy.

There is, however, more innovative work being done in the light metals sector, specifically aluminium, magnesium, titanium and the development of alloys. Down stream possibilities of these metals are large enough to warrant significant levels of research and development. One of the major focus areas of this trend is the development of a cheaper, continuous extraction processes for magnesium and titanium.

9.4 Description of Leading Technologies

The technologies that were identified as important for the metals and minerals industry will be described in greater detail in this section of the report.

9.4.1 Alloy Technologies

Alloys can be defined as a process of combining metals to combine the character elements of the metals combined. Two methods of creating alloys are:

- Conventional alloys consist basically of a disordered solid solution of one or more metallic compounds (e.g. 304 stainless steel has the composition of Fe and 18% Cr and 8%Ni)
- Intermetallic compounds are a particular chemical compound based on a definite atomic formula (e.g. Nickel aluminide is Ni3Al

The applications of alloy technology are too numerous to mention and can only be limited by the needs required by some of the following sectors

- Automotive – strong, light alternatives to steel for components
- Aerospace – strong, light alternatives to steel for components, strong and flexible components for various applications
- Chemicals – metals that have chemical resistant abilities

Alloy technologies should have a significant impact on the majority of the economic factors and at least a moderate impact on a number of the socio economic focus areas. This technology will have major impacts on export growth and access to new markets, such as motor vehicle components, which use an alloy combining steel and magnesium to deliver strong light components. The same holds true for improved product quality, a reduction in the time to market, due to certain curing processes by alloy technology and the utilization of this technology to create jobs and BEE upliftment.

Alloy technologies for magnesium, is a specific focus area in the USA, as magnesium is starting to be used in a wider range of applications such as automotive, Aerospace, cell phones, laptops, etc. The main factor, constraining wider use, is that there is very limited knowledge on alloys, as very little work has been done on developing magnesium alloys to address problems such as corrosion resistance, etc. This is contrasting to aluminium, where there is many years experience on alloys, as the US Government invested heavily in these developments since the 1940's. Developing new alloys would lead to greater use, which would in turn lead to higher production, more "robust" sources and lower prices.

China has also emphasized this area in terms of technology developments, as a pilot project on "magnesium alloys development and applications" has been established, funded by federal and local governments.

9.4.2 Light Metal Extraction

Currently the extraction process used for both these minerals are expensive, this is particularly true of titanium. The benefit of this technology is light weight ultra strong material with applications in various products and sectors.

Both Magnesium and Titanium are used in alloys to create light weight ultra strong metals in sectors such as:

- Automotive
- Aerospace
- Metals
- Minerals
- Agro processing
- ICT

Light metal extraction for magnesium and titanium will have a significant impact on the whole economy, due to the high demand for light weight ultra strong materials in a number of markets like Aerospace and automotive (e.g. car parts). A significant impact will also be made on a number of socio economic drivers such as job creation and BEE.

The USA also regards light metals extraction techniques, especially for Titanium, to be very critical, due to the fact that Titanium is currently about $14/lb, which greatly limits its potential markets. The FFC direct extraction process (invented at Cambridge University, but under development in many sites) could have the potential to reduce this to $1/lb, which would open up huge potential opportunities, displacing steel in many areas. The basic research in this area has already been done and the focus is now at the pilot plant stage.

China has also emphasized the lower cost processing methods for titanium as a key area, in terms of technology developments.

9.4.3 Waste Treatment

Waste treatment will have a significant impact on all environmental factors, of which the most obvious significant impact will be on the environmental aspects, where waste reduction in the process of extracting and processing metals causes major environmental damage. This will however only make moderate impact on the majority of the economic factors, if this technology could be exported to other countries.

The USA also identified this area as an area of focus, as waste treatment of all metals have increasing awareness and importance to the "industrial ecology", with waste in the production process being used as a feedstock for something else. There are only slow movements in that direction at present, which ties in with downstream beneficiation, since it would imply recovering metals/ores that are currently left in the tailings.

Some regions, such as California, are even starting to mandate minimum volumes of cullet (waste glass) into raw material, as a way of sustaining resources. The New South Wales state government has also identified the dumping of glass into landfill, as a waste of resources. Texas also uses large volumes of ground waste glass as a road base, as it cannot be used in buildings concrete, since it would crack.

China has also emphasized this area in terms of technology developments.

9.4.4 Nanotechnology in Ceramics

Nanotechnology is defined as the fabrication of materials and devices with atomic or molecular scale precision. Nanotechnology is rapidly becoming the next global revolution with US-EU-Japan governments spending at least US$2 billion in developing this technology to its full potential.

Nano-technology in ceramics is where Nano particles TiO2 and ZnO are used in coatings, as they have stronger surface finishes that could eventually lead to "self healing" paints for minor scratches. Various applications are starting to emerge in automotive paints, which at present account for about 50% of ceramic nano materials. Other applications are in pharmaceuticals for skin creams, as very fine particles gives transparent sun block, as well as in refractory, which will have better corrosion/erosion properties and a longer campaign life with nanoparticles. In ceramics, nanotechnology should work well, because there are large potential applications in wear materials, which is a major problem area for the industry.

Many areas that presently form part of biotechnology will be engulfed by this new discipline like

- Biosensors
- Nano-scale devices with medical application

The application of nanotechnology within the ceramics entails the use of nano powdered ceramics to construct ceramic components with very detailed design specifications, such as:

- Composite materials containing nano powders or crystals
- Materials based on carbon tubes and fullerines
- Nano coatings
- Nano structured metals and alloys

The benefits of this method of fabrication is only in its infancy but include aspects such as

- cost reduction in production
- quality of fabrication
- effective use of natural resources

At present R&D on advanced materials in South Africa is limited. The current activities are too small and uncoordinated to have a real impact on the economy. The Advanced Metals Initiative (AMI) is however starting to coordinate activities along the complete beneficiation value chain.

Wear is all about surface effects and microstructures, so if this could be controlled, you would be able to build materials with very high performance properties, by controlling the microstructures that would not otherwise be possible. The US military has determined that there are very large savings possible from using nanomaterials to reduce lubrication needs. Although this does not really apply to ceramics, nanotechnology could also be used to separate out CO2, an area of concern for Australia w.r.t. their power stations and other technologies. Nanotechnology will also be used in plastics filled with minerals, to give composites, which will replace a lot of steel for so called “green cars”. There is also a potential used in Aerospace and in sports goods, such as tennis racquets from nano carbon.

Nanotechnology ceramics will also be used for catalytic converter honeycombs (automotive) to reduce bulk, increase surface area and to use less precious metal catalyst.

The University of Queensland is putting a lot of effort into nano-technology, and there is a lot of government support in Australia for this area. A lot of this effort is diverted into the biotechnology area, but minerals are also seen as a potential application.

9.4.5 Advanced Ceramics

Advanced ceramics have an especially high potential to resolve a wide number of today's material challenges in process industries, power generation, Aerospace, transportation and military applications. Such applications are vital to maintaining global competitiveness, decreasing energy consumption, and minimizing pollution. In the past three decades, breakthroughs in advanced ceramics have enabled significant new technology capabilities that are now having far-reaching impacts on the U.S. economy and society. For example, ceramic catalytic converters are responsible for reducing automobile emissions and long-life bearings are used in a wide range of applications to improve performance and reduce friction. The U.S. market value of advanced ceramics was nearly $7.5 billion in 1998, and this value is projected to grow to $11 billion by 2003. More importantly, ceramics leverage much larger economic and social benefits. Catalytic converters alone enable a $38 billion pollution control business each year and have reduced air pollution by 1.5 billion tons since 1975. Ceramic composite materials are tough enough to replace metals in some high-temperature engine applications.

Ceramics have also been developed that are superconducting at temperatures above 100K, polymers have been synthesized that can withstand the impact of a high-powered rifle bullet, diamonds can now be grown at atmospheric pressure, rather than in immense high-pressure presses, and in a area where the fields of materials science and nanotechnology come together, researchers have discovered novel processing techniques to produce nanophase metal and ceramic structures with mechanical properties vastly superior to conventional metals and ceramics.

Advanced ceramic materials that serve electronic and electromechanical functions represent the largest current market.

The new electronic materials include super conductor ceramics consisting of mixed oxides containing rare earth oxides and copper oxides. There has been a substantial increase in the use of piezoelectrical devices

Plenty work is being done in light weight, ultra hard material development (ceramic nitrides, advanced oxides, zirconiums, boron nitrides. The mature markets for advanced ceramics in the electronic industry include:

- Insulators
- Substrates
- Capacitors
- Integrated circuit packages
- Magnetic ferrites

- Piezoelectric ceramics
- Engine components
- Cutting tools
- Bone and tooth replacements

9.4.6 Auto catalysts

Auto catalyst are mainly used as a method of reducing environmentally harmful emissions from some form of combustion process

This technology can be used to reduce these emissions in any application such as automotive, metals and minerals sector, mining etc.

South Africa is currently producing a lot of platinum for the automotive auto catalyst sector and currently no down stream beneficiation is taking place in this sector

Research is also being done to use gold in the catalytic process. The major benefits of this technology are from an environmental point of view by decreasing the components that are harmful to the environment. There are also a number of economic factors such as export potential and access to new markets.

As stated above current products using this technology is catalytic converters in lead free vehicles, but the potential is any combustion process emitting harmful elements.

9.5 Cross Sectoral Impact of Leading Technologies

The table below depicts the cross sectoral impact of the leading technologies. As can be seen, there is impact across almost all sectors.

Table 30: Cross sectoral impacts

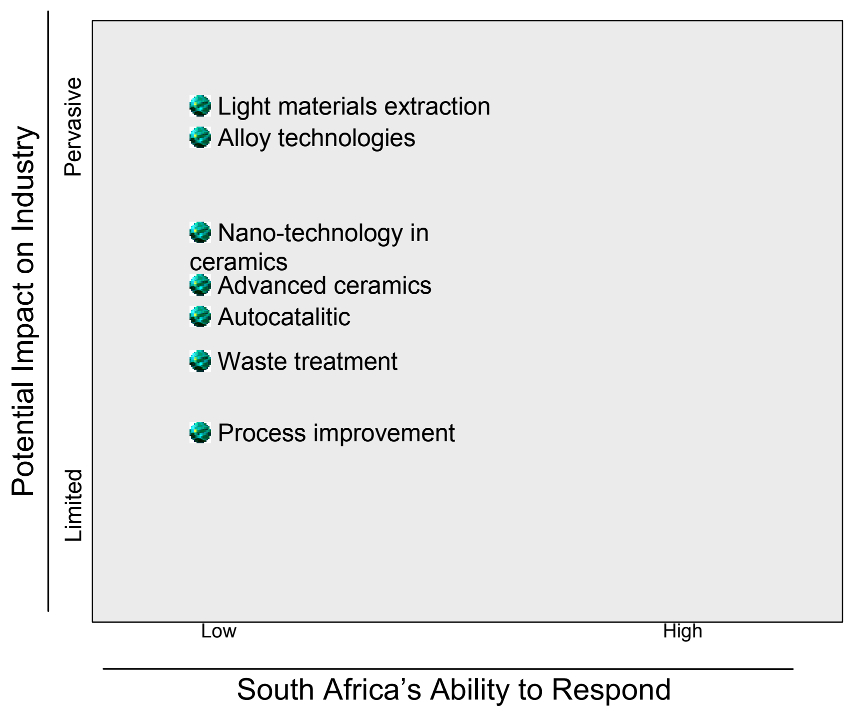
Technology	Agro	Chem	Met	Min	Auto	Aero	ICT	Tour	Biotech	Cul I
Alloy Technologies	X	X	X	X	X	X	X			X
Light metal extraction	X		X	X	X	X	X			
Waste treatment		X	X	X	X	X				
Nanotechnology in	X	X			X	X	X		X	X

Ceramics										
Advanced ceramics	X	X	X	X	X	X	X	X	X	X
Auto catalysts	X	X	X	X	X	X				

9.6 Conclusions and Recommendations for Sector Development

Based on the assessment of key emerging technologies, their relative expected impact on the Metals and Minerals Industry per se, and South Africa's ability to respond, or take advantage to such technological development, the following is concluded.

Figure 17: Impact analysis grid



The above section identified the major technologies for the Metals and Minerals Industry. Considering South Africa's current strengths and weaknesses in light of the opportunities (and threats) presented by these technologies, the following should be considered:

Light metal extraction techniques and alloy technologies, especially in magnesium should be a primary focus and present significant opportunities. Not only are these technologies a primary focus within demand sectors such as automotive in which South Africa has a significant presence, but also on the supply side. There is therefore opportunity for combined R&D across the value chain. The Advanced Materials Centre of the CSIR and the Advanced Materials Initiative of the CSIR and Mintek is a strength from which world class capability can be built.

- Waste treatment is becoming more and more critical, globally and South Africa should not be left behind in this area.

Although autocatalytic is internationally perceived to be an important emerging technology, it is not seen to have the same relative potential impact on the Metals and Minerals sector as for example lightweight materials. This is due to the primary focus in waste reduction being on reducing the intensity rather than technologies for reduction. However, this does not negate from the fact that it presents significant opportunity for South African industry, mainly due to a number of strengths in this area, such as highly developed upstream sectors (gold and platinum), existing manufacturing presence (catalytic converters) and expertise.

Advanced ceramics (and especially nano-technology for ceramics) is internationally perceived to be emerging strongly for application beyond the electronic and electro technical industry in other manufacturing industries such as machinery, equipment, automotive, and medical devices. Although South Africa has pockets of expertise and ongoing R&D in certain areas, the overall conclusion must be that South Africa is not positioned to exploit such technologies for industry leadership, in general. This does however not imply that in is a threat to the South African Metals and Minerals Industry, but specific areas of opportunities unless pursued, could mean opportunity for increased competitiveness and market-share is lost

9.7 Technology Support for Sector Development

This section highlights programmes and support for the metal sectors in various countries. It also points to concerted efforts made to enhance the competitiveness of the sector in that particular country.

9.7.1 United States of America

Metals are an important industry sector in the USA, primarily due to the fact that the USA is a major user of the metals and it therefore supports a variety of different industries. The USA is also a leading manufacturer of major end use products such as automobiles, domestic appliances, construction, etc. US demand for different metals is

- About 22% of the world total for aluminium
- 19% of platinum
- 19% of stainless steel
- 40% of titanium, etc

The USA has also become a major importer of both raw materials and semi-finished metal products, due to the big demand local.

The USA government has introduced a number of support mechanisms and policies to ensure the competitiveness of the automotive industry. These include:

- The Bureau of Mines no longer funds any research, which reflects an apparent limited interest in raw materials.
- The National Material Advisory Board was founded 150 years ago by Congress, and is intended to be the primary source of scientific, technological and policy assessment of materials, processes and applications for use by the USA industry, government agencies and universities .The Board deals with the complete life cycle of materials from, mining to disposal. The Board's assessments of new materials are intended to focus policy issues with significant technology content
- Recent reports have included:
- Materials research to meet 21st century defence needs, which included recommendations for the Department of Defence to invest in the research of (among others) advanced structural composites and lightweight mobile power, as well as the use of lightweight materials in 21st century army trucks

Another relevant Government agency is the Defence Advanced Research Projects Agency (DARPA), the central research and development organisation of the Department of Defence, which manages and directs basic and applied research and development projects for the DOD. Some of the Advanced Technology Office Programmes are relevant to metals, which for example, include an initiative in titanium aimed at developing new production processes.

The National Institute of Standards and Technology is part of the US Department of Commerce

- Part of the NIST is the Advanced Technology Programme that aims at bridging the gap between the research laboratory and the market place, but does not fund product development, is mainly focused on how the project will benefit the nation and operates mainly on joint funding from companies.

9.7.2 Australia

Australia is one of the world's leading mineral producing countries and has the world's largest economic demonstrated resources of lead, mineral sands, nickel, tantalum, uranium, zinc and in the top six for bauxite. As a consequence of the above, the very clear emphasis is on mining and production and not on subsequent processing. Ceramics and glass are of relatively minor importance and is a small industry sector in Australia, even though there are niche companies (e.g. Modern Ceramics, a maker of personal armour).

The Australian government has introduced a number of support mechanisms and policies to ensure the competitiveness of the automotive industry. These include:

The Minerals and Fuels branch of the Department of Industry, Tourism and Resources is the relevant ministry

- The Department has identified a series of Action Agendas for about 34 specific industry sectors, including mineral exploration, mining technology services, and chemicals and plastics, but nothing specifically relates to ceramics or glass
- In 2002, the Department of Education, Science and Training developed a series of national research priorities, and provides financial assistance to for research in four broad areas
  - An environmentally sustainable Australia
  - Promoting and maintaining good health
  - Safeguarding Australia
  - Frontier technologies for building and transforming Australian industries
  - This latter is most relevant to minerals, having five priority goals
    - Breakthrough science
    - Frontier technologies
    - Advanced materials (ceramics is specifically cited as one of the materials)
    - Smart information use
    - Promoting an innovation culture and economy
- There are two or three general schemes for support from the Federal Government, which is where most funding comes from
  - The government supports CSIRO, (Commonwealth Scientific and Industrial Research Organisation) of which mineral resources is part
  - Other sectors are agribusiness, energy and transport, environment and natural resources, information, communication and services, manufacturing and health
  - CSIRO gets an overall $500/600 million grant and sets its own research and spending priorities

- There is also the Australian Nuclear Science and Technology Organisation (ANSTO)
  - ANSTO Minerals is one of their sectors, but the focus is primarily on processing and waste management, rather than subsequent processing
- The Australian Institute of Marine Science also funds research, but this is of minimal relevance to the minerals sector
- For universities only, there is the Australian Research Council
  - The ARC provides funding for pure research over wide areas, of which technology is only one
  - ARC has a scheme (ARC Industry Linkage Programme) to fund joint research (part industry/part ARC) -- the areas are not specific, but there are sectors where the Government seeks proposals (e.g. mining in general, but not topic specific)
  - There are also a number of ARC Centres and Networks aimed at supporting large research teams and networks in areas that are considered important and challenging (includes research into functional nanomaterials and nanostructured electromaterials, as well as other areas such as complex dynamic systems and control, and genomics.
- The Cooperative Research Centres programme of the the Department of Education, Science and Training was set up 10-12 years ago. The government funds 50% of the centres, with the balance from industry. These are aimed at bringing together universities, usually CSIRO, and industry. There are again specific areas, one of which is mining, focused on very specific issues, such as coal preparation or hydrometallurgy. The government defines the broad areas of interest (e.g. mining) but no specifics within that. There are 64 of these in universities across Australia, and they usually last for 7 years, but can be re-funded for further periods
  - They cover 6 sectors -- manufacturing technology, information and communication technology, mining and energy, agriculture and rural based manufacturing, environment, and medical science and technology
  - The two CRCs of potential relevance is manufacturing technology encompasses composites for Aerospace, maritime and general applications, and the Hydrogen CRC which is working on fuel cells and hydrogen storage (for which ceramics is relevant)
- State Governments may have some ad hoc support, but there is nothing of significance to glass or ceramics
- The Sustainable Minerals Institute was founded 2 ½ years as part of the University of Queensland, which has a long history of major minerals in industrial activities, education and especially research

  - Research is through a number of targeted R&D areas in centres in the University of Queensland, such as mineral processing, mining, mining geology, environmental, water and social responsibilities
  - The role of the SMI is to identify "big picture issues", and they are very international in scope (including South Africa). Funding and sponsorship is from industry. SMI tries to identify big challenges and then solve them. The challenges are brought to them by industry (e.g. mining closures or mass mining). SMI got some one-off funding from the Queensland State Government when they started.
  - Research areas include issues such as water, environment and mine closure and sustainable development

- The Australian Institute for Commercialisation is an interesting support "facilitating" organisation in Australia, but it does not have a sector focus
  - The organisation is a national, not-for-profit company that was initiated (and initially funded) by the Queensland Government to improve the return from the public sector investment in research
  - The aim of the AIC is to act as a catalyst between funding organisations and research bodies, focused on converting research into commercial activities
  - There are three operational themes at present
    - AIC Connect is a platform aimed at providing networking and improving economies of research scale
    - www.aussieopportunities.com is a national e-marketplace for innovation and invention
    - AIC Know-How is aimed at addressing the shortage of skills in commercialisation
    - AIC Assess measures outcomes of commercialisation to give more effective management

- The Government has not really looked at other mechanisms -- education is block funded and they then decide themselves where to allocate it.

9.7.3 China

China is the world's largest producer of primary aluminum and its aluminum consumption is growing at an annual rate of over 10%, as a result produced 5.2 million tons of primary aluminum, in 2003. The Aluminum Corporation of China (Chinalco), which is dually listed on the stock markets in Hong Kong and New York, is the world's third largest alumina provider. China's own production of alumina of 5.5 million tons (2003), cannot match its (electrolytic) aluminum capacity 6.29 million tons (2003), resulting in an import of 5.61 million tons of alumina in 2003. China's capacity for engineered aluminium is larger than (electrolytic) aluminium, due to the fact that, normally, for one ton of (electrolytic) aluminium, more than 2 tons of alumina needs to be consumed. China's bauxite supplies are abundant but of poor quality, which makes them both expensive and difficult to process. This combination of poor quality and unusual composition of bauxite, have forced the Chinese to perfect a unique sinter process, that requires more than three times the energy of a western plant, using traditional Bayer technology.

There are over 130 Aluminum smelters in China; most of these smelters have a capacity of less than 50 kt. and only nine smelters have installed capacity in excess of 100 kt. Not only are those smaller smelters uneconomic, they are highly polluting (Soderberg technology)

The operating costs of most large Chinese smelters also would place them in the highest-cost quartile of the world's primary aluminum capacity.

Despite the rapid increase of China's overall aluminum consumption in recent years, per capita consumption still amounts to little more than 2kg – compared to 35kg in the United States; so there is ample room for further growth.

Since 1998, incentives such as interest free loans, low cost land use rights have been provided by governments at different levels to encourage the development of the aluminum industry.

Investment cost in China in terms of per ton smelter capacity is 50% less than in the West.

9.7.4 China's Aluminum Industry

Trend

The gap between alumina demand and aluminum production will almost certainly widen over time.

The government is encouraging investment in other countries to secure supplies of alumina.

The aluminum industry is now considered "overheated" and as a result:

- The central government has lowed tax rebate rate for exports

- Practice of duty exemption policies for imported capital equipment will be tightened
- Smaller, uneconomic, and polluting smelters will be shut down in proportion to capacity additions in larger smelters.
- Soderberg technology will be ”forced out “ by the end of 2004
- Emphasis will be placed on health and safety programs, environment, and aluminium scrap recycling…
- Mining of bauxite will be more strictly supervised.
- The government would also encourage technology development for wider application of aluminum in the manufacturing sector particularly automotive.
- Chinalco’s monopoly position for alumina is being “questioned”

9.7.5 China’s Magnesium Industry

Overview

- China is endowed with some 22.5% of the world’s magnesium ore reserve.
- With annual production accounting for some 50% of the world’s total, China is now the largest primary magnesium producer and exporter.
  - In 2003, China produced 354,000 tons of primary magnesium
  - In 2003, China’s export of primary magnesium amounted to 298,000 tons
- Chinese primary magnesium producers have a combined market share of up to 65% in the European Union.
- By 2002, there were more than 100 magnesium enterprises.
- Cost competitive Chinese primary magnesium is forcing Western produces to give up primary magnesium production and focus on higher value added magnesium alloys.
- Chinese competitiveness in primary magnesium is accomplished through low labor cost and sacrificing environmental interest
- The VAT rebate rate for export will remain unchanged at 13% despite a recent average cut of 3% for most export items.
- Production of magnesium has been enjoying double digit growth in recent years.

9.7.6 China's Magnesium Industry

Trend

- China is shifting focus from churning out primary magnesium in quantities to developing magnesium alloys for more added value.

- A pilot project on "magnesium alloys development and applications thereof" was kicked off in August 2001.

  - RMB 41 million ($4.9 million) in direct central government allocation
  - RMB 600 million ($72 million) in support funding from various sources (local governments, companies, research grant etc)
  - 4 research institutes, 7 universities and 20 enterprises are involved

- The project was designed to help the Chinese magnesium industry move up the value curve.

- So far, some progress has been made in applying magnesium alloys to motorcycles, bicycles, shells for laptop computers and cell phones…

- Also some Chinese companies are exploring applications of magnesium alloys to the automotive industry.

- An industry consolidation is inevitable, which would result in smaller polluting players being "forced out".

9.7.7 China's Titanium Industry

Trend

- The chemical industry will continue to consume the largest portion of titanium production.

- Demand of titanium for making electricity generating equipment will reach up to 1,000 ton per year.

- China is beginning to use titanium for the construction of buildings – the State Opera House is a monumental case.

- Reportedly, titanium is also being introduced to the automotive industry.

- Demand for titanium in marine, medicine, sports, national defence applications is also expected to rise.

- “The western development strategy” and the “Reinvigorating the Northeast ”campaign are expected to be conducive to the development of the two titanium manufacturing bases there.
- To align titanium production with steel as in the case of Baosteel Group will help consolidate fabrication of engineered titanium.
- Greater emphasis will be placed on treating “three wastes” in the process of titanium extraction/production.
- Reportedly, factories, universities and the Titanium Industry Association are all pushing for more government support for the research of “FFC method”, which could reduce production cost of spongy titanium by 50%…

9.7.8 China’s Metals Industry

Government Support

The Government support appears to be of a “generic” nature, rather than being focused on the metals area specifically (as in the case of minerals):

- This would include such levers/incentives as: low/ free land use right (from local government), VAT refunds or waiver (funded both by central government and local government)
- Wholly government funded projects (funded both by central and/or local government)
- Duty and VAT exemption for imported capital equipment
- Tax incentives for exports
- Interest free or interest subsidized loans
- Recommendations to the World Bank or to foreign governments for funding.

In terms of how the support is allocated, this is based primarily on political aspects of specific projects and “Guanxi” (connections with stakeholders), government priorities... different government departments:

- The sense is that while there may be a grandiose government plan for specific sectors, in reality companies in most cases need to compete for limited resources, often through means of personal connections.

9.7.9 China's Glass Industry

China's Glass Industry Background

Based on these discussions it appears that the Chinese emphasis in terms of technology developments is focused more on increasing productivity than on issues such as environmental concerns.

China's Glass Industry Overview

China is the largest producer and consumer of plate glass in the world.

It is estimated that China's market demand for plate glass was between 207~226 million cases in 2003.

Chinese plane glass manufacturers are focusing on technologies such as:

- Raw materials, melting, molding, and annealing for float glass
- Super thin
- Rollers of annealing furnace
- Simultaneous laminating
- Oxygen burning
- Dual line from one furnace

China's Glass Industry Government Support

- The Government support appears to be of a "generic" nature, rather than being focused on the minerals area specifically:
- This would include such levers/incentives as: low/ free land use right (from local government), VAT refunds or waiver (funded both by central government and local government)
- Wholly government funded projects (funded both by central and/or local government)
- Duty and VAT exemption for imported capital equipment
- Interest free or interest subsidized loans

Recommendations to the World Bank or to foreign governments for funding.

In terms of how the support is allocated, this is based primarily on political aspects of specific projects and “Guanxi” (connections with stakeholders), government priorities... different government departments:

The sense is that while there may be a grandiose government plan for specific sectors, in reality companies in most cases need to compete for limited resources, often through means of personal connections.

THE CULTURAL SECTOR

10 TECHNOLOGY DEVELOPMENT TRENDS OF THE CULTURAL SECTOR

10.1 Summary

Cultural Industries is a large global industry and has a huge potential in job creation and also offers an opportunity to develop less favoured regions. New and original industries emerge not necessarily from the use of new technologies, but from creativity, skills or traditional materials. This makes crafts and tourism related industries a springboard for development. Internationally, the cultural industries are recognised as having significant economic benefits. Past figures of culture sector's contribution to GDP and employment illustrate the economic and job-creation potential of cultural industries.

South Africa's diverse and dynamic arts and culture heritage is one of its richest and most important resources, with the capacity to generate significant economic and social benefits for the nation. Equally important, but less well understood, is the potential for a vibrant and dynamic arts and culture sector to contribute significantly to the economy of the country.

Crafts are the visible part of the iceberg of cultural diversity. The added value of craft products stems from the fact that they mirror the creativity, culture and heritage of crafts people, it is a major priority for government to grow this therefore major emphasis has been put in developing this subsection, to preserve South Africa's cultural heritage, allowing the provision of jobs that are highly labour intensive and require low technology input.

Certain objectives to grow the sector have been identified by the Department of Arts and Culture namely human resource development, poverty alleviation, job creation, urban renewal and integrated rural development. Another important objective is to ensure that the South African population is an all information inclusive society.

Although cultural industries are an important part of the economy there are constraints causing a backlog, the major concerns are that the sector does not have appropriate training and skill development, urbanisation is causing a lack of transfer of traditional skills within the families, there is a lack of knowledge management, research and development is literally very minimal. Other constraints include access to raw materials, skills development, finance, support services and problems within areas relating to marketing, infrastructure as well as production.

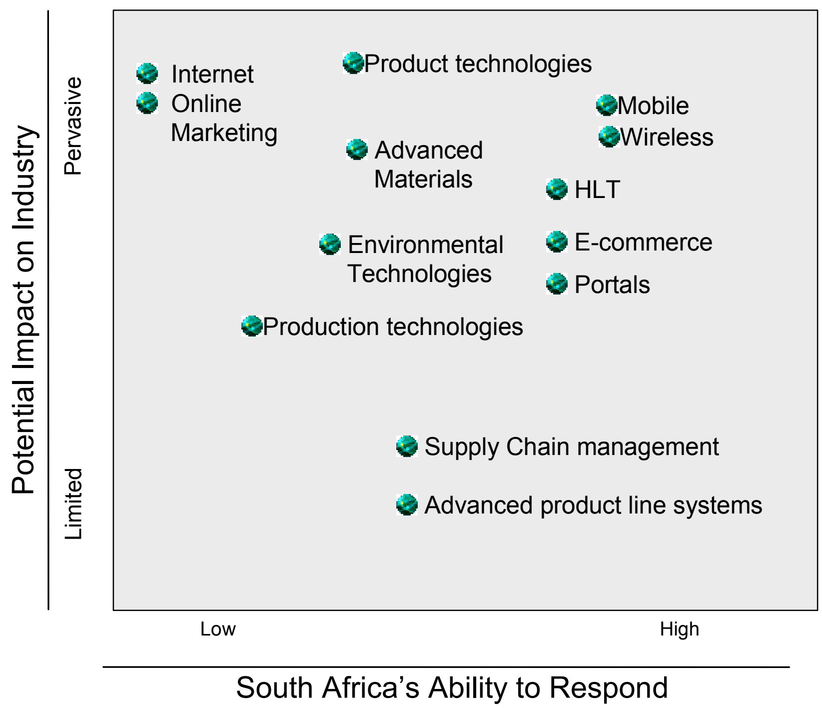
Various experts within the industry have come to the agreement that the cultural industry lacks the knowledge of what the customer wants. The participants within the cultural industry are therefore developing products and designs but do not understand what the customers' needs are, causing an over supply of products with an under-demand for the purchase of these products. As a result marketing and the end-consumer require more attention.

In identifying technologies to alleviate these issues it is necessary to have a look at the cultural industry particularly arts and craft on a value chain, this value chain has five sub-categories beginning with idea generation, design and product development phase; concluding with the end-consumer.

The most important technologies which are an incremental part of developing the sector is enabling communication technologies, technologies which improve the product and the technologies that provide marketing to the end-consumer.

The most important technologies are depicted on this grid below:

Figure 18: Summary of technologies



Although there are a wide variety of technologies to support the cultural industry, given South Africa's unique situation and objectives to create jobs, improve the quality of life, to have economical growth as well as be an all inclusive information society, the table above summarises the key supporting technologies which are necessary to sustain and grow the industry.

The greatest impact on the sector are online marketing tools consisting of e-commerce, internet and other such technologies which will enable access to international as well as local end-consumers

The Internet is rapidly becoming an effective and efficient means of communication and marketing for crafts-makers, but it is positioned at the top left hand side of the positioning grid. For South Africa to take advantage of the internet as a means to market the products and services it will require an increased broadband capacity, better infrastructure and content provision as well as service provision.

Some of the means to optimally utilise the internet are designing of websites that are dedicated to developing and promoting the sector. These websites should include virtual crafts fairs, providing e-commerce for crafts in general and specific sectors, for example, beadwork, ceramics, glass, jewellery, textiles and woodcrafts. These sites should also contain chat-rooms, which offer the opportunities to promote and advertise craft products as well as the services that are provided by the artist. Individual makers can use the internet as a means to publicise and sell their work.

The cultural sector has the capacity to be both a source of the South African identity and also be a setting for the development of innovative activities that boost job creation. There is a growing correlation between culture and employment but it is however underestimated. The activities that have the best prospects are arts and crafts, heritage and activities linked to new technologies. The best way to develop this is by giving these issues the correct support and attention that it deserves.

As running a crafts business requires both artistic and business skills, one key issue for makers is the lack of knowledge and experience of administration and business management. This may constitute a significant barrier to entry into the market.

Therefore improved training opportunities in business skills and the management of resources are required as well as transfer of skills. As technology becomes an increasingly important means of communication and marketing for crafts-makers information, support and training in ICT skills should be made more available.

Professional crafts-makers need the resources and opportunities to conduct research to develop and improve their skills and experience.

The crafts sector would benefit from closer links with related industries. There are great similarities, for example, between textile crafts and the textile industry therefore the support for cross-industry working is needed to promote the development and expansion of the sector.

An important factor in the development of the sector is the quality of market information and of industry analysis. Crafts are a complex and fragmented sector which is difficult to define and classify. Improved knowledge of current and potential markets and of more effective ways to target them should greatly enhance the growth potential of the industry. This quality of market information will be able to be accessed through having entrance to technology platforms like mobile and wireless technologies as well as the internet.

10.2 Context of Sector

10.2.1 Defining Cultural Industries

Arts are the expression of a people's ability to invent its future by drawing on the genius of its heritage, enriched by contact with other cultures. The term "cultural industries" is used to describe a wide variety of cultural activities which all have commercial organisation as their prime motivating force. These activities take a number of different forms and are organised in different ways from the manufacture or creation of products to the marketing and distribution thereof.

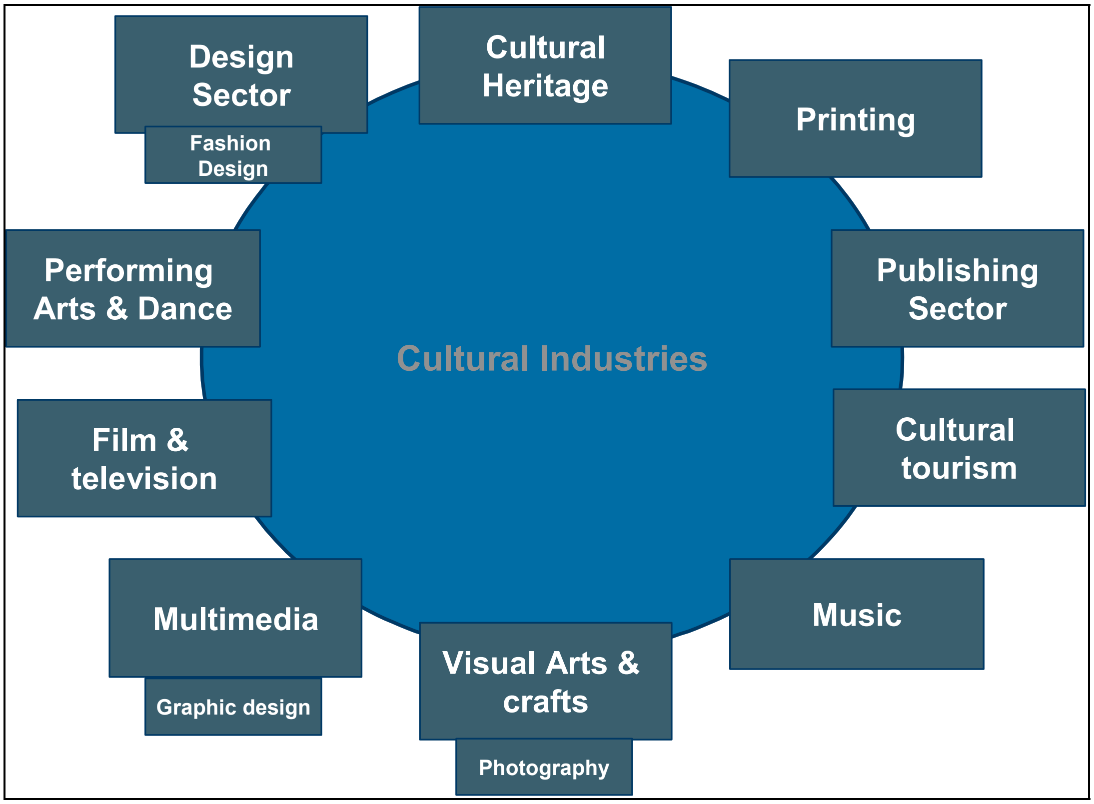
The cultural industries tend to be:

- Knowledge intensive, involving highly skilled workers
- Labour intensive, creating more than the average number of jobs
- Differentiated, taking the form of small and medium enterprises (SMMEs) and large enterprises
- Linked with close, interlocking but flexible networks of production and service systems, allowing the sector flexibility in the face of economic recession (Unesco, 2002)

Cultural industries add value to contents and generate values for individuals and societies. They are knowledge and labour-intensive, create employment and wealth, nurture creativity - the "raw material" they are made from -, and foster innovation in production and commercialisation processes. At the same time, cultural industries are central in promoting and maintaining cultural diversity and in ensuring democratic access to culture. This twofold nature –both cultural and economic – builds up a distinctive profile for cultural industries. During the 90s they grew exponentially, both in terms of employment creation and contribution to GNP. Today, globalisation offers new challenges and opportunities for their development.

A typical structure of the cultural industry can be depicted with the following diagram.

Figure 19: Typical structure of the cultural industries



Cultural industries" cover film production, the audiovisual sphere, the printed word and also multimedia (a sector that is in full expansion and breaking all production records, even in non-industrialised countries). However, there is still some dispute as to the definition of this sector. Some countries include architecture, the performing arts, and even the plastic arts and cultural tourism.

Countries such as Scotland and New Zealand also have fashion design, graphic design as well as photography as part of their sub sectors. South Africa's main focuses at the moment are on Arts and Crafts as well as film & television and printing, the belief is that these are the potential platforms for future development and job creation within the country.

10.2.2 Cultural Industry from a Global Perspective

Internationally, the cultural industries are recognised as having significant economic benefits. Past figures of culture sector's contribution to GDP and employment illustrate the economic and job-creation potential of cultural industries.

For example:

- The craft industry constitutes 15% of Morocco's GDP
- The Canadian cultural industries generate $22 billion and generate 670 000 jobs
- In Mexico, cultural tourism contributes 6% to GDP
- Arts and culture contribute 3% to Australia's GDP, generating $36 million per annum (CIGS, 1998: 12)

Within OCDE countries, the culture sector accounts for 4% of GDP while it accounts for 1 to 3% in developing countries (i.e. 1% Brazil). In Canada, around 5% of the GDP labour force engages in cultural industries, compared to 2.8% in the United States of America and 17% in South Africa.

It is important to take note that every country has a different definition of the cultural industries; it is for this reason that there is a varied amount of GDP which this sector contributes to the overall economy.

10.2.3 Global Drivers of Change

The cultural industry is an industry with a lot of vibrancy and dynamism therefore it is changing on an on going basis. Some key emerging trends include:

- Countries realising the potential of sector growth through the use of technologies and are therefore establishing efficient systems to support the creation of new technologies, products, processes, services and markets
- An increase in focusing on a cleaner environment due to global warming, the ozone layer and pollution therefore encouraging the development of environmentally-friendly and energy efficiency technologies. These technologies include renewable energy sources, biodegradable material, cleaner production processes and the reusing of waste materials
- The world becoming a global village is creating an increase in cultural diversity
  - Eastern and African cultures are meeting Western cultures, these designs are blended to an extent where products are designed in Europe, manufactured in the East and then marketed internationally.

- An increase in accessibility to information and knowledge creating the environment for innovation. Innovation is a key driver for competitiveness

- Convergence of information, communication and entertainment industries through digitisation of content and it holds the potential to be a source of innovation and technological development

10.2.4 Cultural Industry from a South African Perspective

South Africa's diverse and dynamic arts and culture heritage is one of its richest and most important resources, with the capacity to generate significant economic and social benefits for the nation. Equally important, but less well understood, is the potential to create a vibrant and dynamic arts and culture sector which can contribute significantly to the economy of the country.

Crafts are the visible part of the iceberg of cultural diversity. The added value of craft products stem from the fact that they mirror the creativity, culture and heritage of crafts people. It is for this reason that the majority of our focus within the cultural industries will be on developing the arts and crafts sub-sector, in order to preserve South Africa's cultural heritage allowing the provision of jobs that are highly labour intensive and they require a low technology input.

10.2.5 Sector objectives

Within the South African context the Department of Arts and Culture has identified a number of national strategic objectives, they have also linked various programmes with the aim of achieving this these objectives among others are human resource development (HRD), the development of creative skills as well as business skills, poverty alleviation, job creation, urban renewal, and an integrated rural development (www.dac.gov.za).

10.2.6 South Africa's position

Following is an overview of South Africa's strengths, weaknesses, opportunities and threats. This will place South Africa's position within the cultural industry into context

Table 31: South Africa's SWOT analysis

STRENGTHS
• It is an important contributor to employment especially within rural communities • It is a low technology sector • It is highly labour intensive • South Africa has a rich cultural diversity and heritage • South Africa has an excellent foundation for developing products

- There is little restrictive legislation for the production and selling of cultural products and services
- There is reasonable amounts of Government and Agency support to develop the sector
- There are low entry barrier for entrepreneurs

WEAKNESSES

Skills:

- There is poor human resource development and technical skills
- The sector has inappropriate training and skill development
- Urbanisation is causing a lack of transfer of traditional skills within the families
- There is a lack of knowledge management:
- Research and development is literally very minimal
- The industry generally constitutes of very low technology processes so there is little technology investment
- There is a failure to acknowledge intellectual property rights
- Lack of preservation of knowledge that resides in communities

Product:

- Integration of appropriate craft products
- There is poor material research in ceramics and natural paper based materials
- There is a lack of materials testing and performance measurements
- There are Inappropriate energy supply sources in rural communities so They can't use various technologies and techniques to create their designs
- There are high sourcing costs and high costs to access raw materials
- There are high costs in capital equipment due to financial costs and constraints

Processes:

- There are weak global supply links and the global capacities are therefore not able to be measured
- There is a lack of resource collaboration and enhancement of labour productivity
- Labour intensive operations are not complimented by simplified methodologies and designs

OPPORTUNITIES

- Taking advantage of exchange rate and export finished value-added commodities rather than raw materials only
- Develop and create intellectual property and sell to the rest of the world
- Create new way of doing things
- New ethnic
- New experience
- New identity
- Proud cultural heritage that is known worldwide
- Create good quality products while still maintaining the cultural heritage and design

THREATS/BARRIERS

- Increased competitiveness from neighbouring and other countries
- A slow deregulation and poor preparation for global challenges
- Loss of jobs
- Needs occurring for heavy investment in environment reconstruction and protection.
- High labour costs
- Blackmailing sub-suppliers, weakened by the old competencies
- Illiteracy to new technologies
- Poor production rate due to lack of crucial Know-how which could integrate ancient traditions with the possibilities offered by new technologies, in particular those of ICT and new materials

The most significant constraints or obstacles for further future development can be summarised in the following points:

- Access to raw materials
- Skills development
- Information
- Finance

- Support services
- Problems relating to marketing, infrastructure and production

10.3 Value Chain of the Cultural Industry

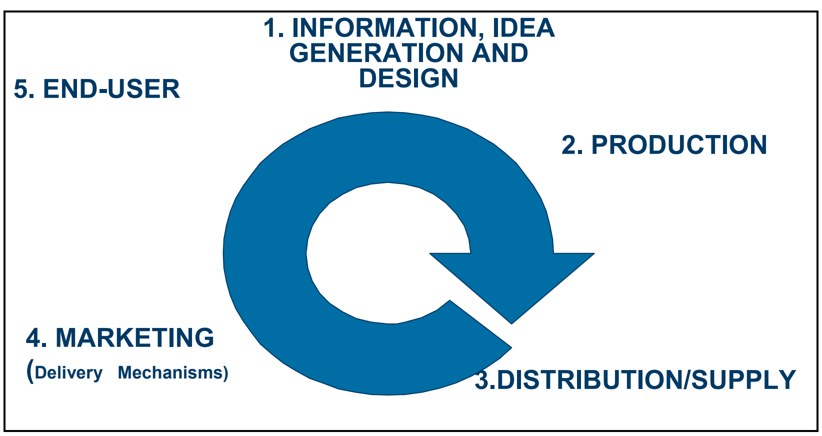
The value chain within the arts and crafts sector typically consists of the collection of information, idea generation and design, followed by production, distribution, marketing and then a purchase by the end-user.

10.3.1 Requirements within the value chain

Within the cultural industry particularly the arts and crafts sector the value chain consists of a typical manufacturing process which is explained a little bit more in detail further in this report. The value chain usually proceeds with innovation and design and concludes with the end-user. After conducting interviews with various industry experts that specifically deal with the cultural industry, there was a concurrence that the cultural industry lacks the knowledge of what the end-customer wants. The participants within the cultural industry are therefore developing products and designs but do not understand the customers needs, rooting the issue of having an over supply of products while under-demand in the purchasing of the products.

Figure 2 below visually depicts an outline of a typical value chain, it is necessary to understand what the requirements are within each category. This understanding will assist in identifying the various issues which need to be addressed, thereby establishing possible technologies to provide solutions for a sustainable sector.

Figure 20: Value chain within the cultural industry



10.3.2 Information, Idea Generation and Design

The first part of the value chain consists of the supplier collecting information with regards to the end-users requirements, generating ideas around the needs and then creating a design for product development.

The requirements needed to make it a success are:

- Skills transfer
- The ideas within the context
- Cultural heritage
- Finance and funding
- A wide array of cultural needs and talents

10.3.3 Production

Production is the process of actually making the product and then providing a platform for the product/service to be purchased as well as viewed. In order to make the production aspect within the value chain successful it requires the following:

- People (designers)
- Processes and knowledge
- Raw materials and new materials
- Sites of productions and facilities
- Equipment and Correct tools

10.3.4 Distribution/Supply

Various channels of supply are extremely important in order for the product to be accessible to customers. The distribution channels can potentially be divided into 3 areas namely arts and crafts that are distributed through cultural tourism, through traditional channel of supplies (distributors, agents, marketers, intermediaries and suppliers, supply chain management, traditional communication facilities like brochures, catalogues etc.), another important means of distribution are global channels, the internet is utilised and potential customers can purchase goods using e-commerce and plastic money i.e. credit cards.

10.3.5 Marketing

A product seldom has the capability of being sold in high volumes unless there is a need for it or the products/services have a substantial amount of awareness made around it. They therefore need to be advertised, branded and sold to the consumer. Successful marketing requires a fine balance between all the elements of the marketing mix [product, pricing, promotion (communication material; online marketing) and distribution (platforms to make products available)]. It is also a vital part of the delivery mechanism. Some of the requirements in terms of marketing the arts and cultures are: exhibitors, broadcasters, retail outlets, live venues, performance spaces, Gallery/ exhibition spaces, brochures as well as global electronic channels.

Other important factors that can't be excluded from the marketing sub-section of the value chain are the research and development of new products of the network, research and development of technologies and innovations necessary in order for the products to be economically viable and to meet the market demand; positioning of the products produced by the network in niche markets at an international level; commercialisation with the least possible amount of intervention; reducing the length of the value chain; the provision of advanced logistical services that reduce delivery times and allow tracking of goods sent; the customer service, invoicing and returns.

10.3.6 End User

The consumer is the person that will ultimately purchase the finished good or service and they have various needs in terms of selecting the end product that they will purchase. Within every nation there are a small group of individuals who are of little interest to those producers responding solely to national markets but of particular importance to all producers selling world-wide.

These individuals have rich cultural backgrounds and high incomes. They come from various countries and speak different languages, yet they communicate and are more in tune with those who share the same cultural perspectives, read the same works, and love the same artists: they constitute a type of virtual community crossing national borders. As consumers they are not easily influenced by "trendy brands" but have precise requirements: they search for products that have soul, but at the same time conform to the technical standards in terms of health and safety.

Running counter to the processes which lead to the standardisation of products and the similar tastes that typify many sectors of the population, these consumers seek authenticity, appreciate the native identities and express a need for personalisation that is demonstrated by their search for limited edition or one-off products. This consumer does not purchase regularly or in great volumes but instead pays attention to the quality and the durability of the product. In having the ability to understand this type of consumer the artisan will be able to have a clearer understanding of the type of product that needs to be produced as well as the quality.

10.4 Technologies to Meet Requirements

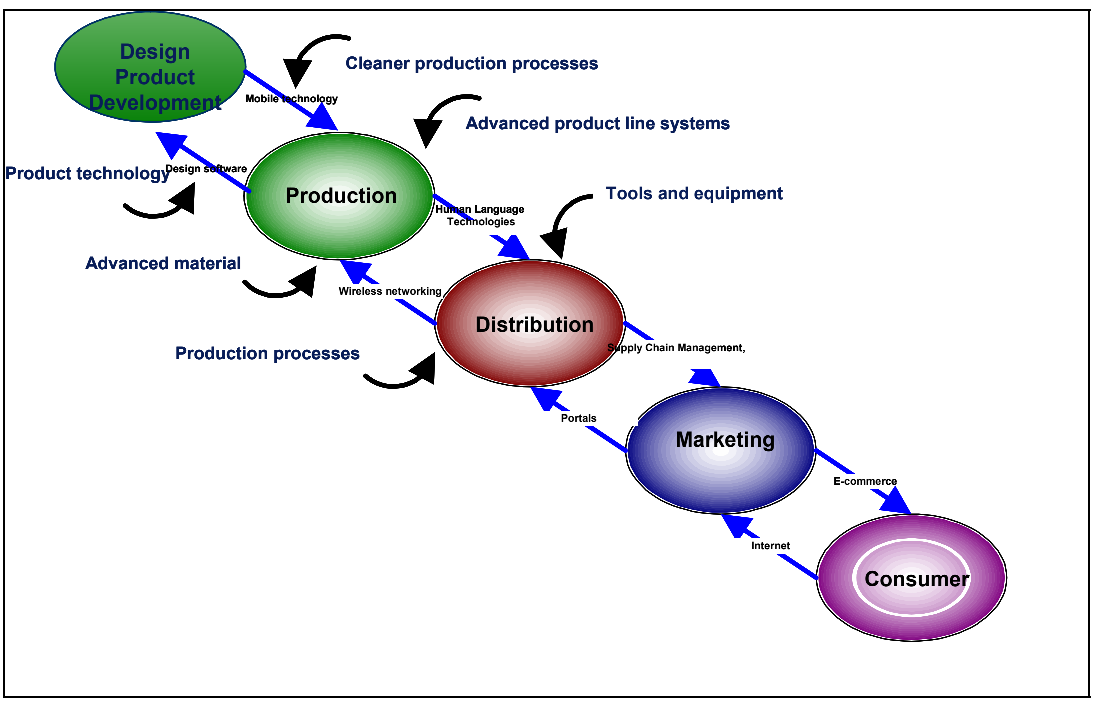
In the context of economic and cultural globalisation, the cultural industry has an ability to create and produce unique high-quality products, with added cultural value. Arts and crafts specifically, represent new fields of jobs and trades which are created with the balance between traditional arts and modern technologies. This reveals significant possibilities for the creation of new products in order to meet new needs.

At present the Craft industry is still underdeveloped and this very significant constraint is linked to aspects like:

- Lack of proper credit facilities and micro-finance services,
- Inadequate access to appropriate communication, transport and utilities infrastructure
- Problems related to deadlines, production processes, volumes, product quality and product development
- Irregular and inappropriate marketing strategies
- Difficulty in obtaining materials for production

The following diagram demonstrates the variety of technologies that can support the industry throughout its life cycle.

Figure 21: Technologies supporting industry within lifecycle



Note the prominence of ICT and all the possible opportunities that it presents to the cultural industry. ICT eliminates geographical and time barriers and allows the distribution and fruition of information from diverse data sources and its integration with other knowledge databases. These technologies can be used as a communication and data management tool for the co-operative management of the whole productive process (from the information, idea generation and development phase up to the commercialisation and end-user phase)

Apart from ICT as enabling technologies artisans are faced with emerging opportunities that can link old crafts to modern technology and produce high quality products, with which to penetrate international niche markets. As mentioned before in today's markets a completely new trend in consumer demand is emerging, irrespective of national boundaries. Keeping all of the above in mind in terms of what the requirements are within each section of the value chain the technology is the great ally that combines models of learning , models for economic, territorial and business growth, creating a wider "innovative network".

10.5 Detailed Description of Significant Technologies

Mention has been made of the technologies that will be effective in meeting the sectoral requirements. Now in order to gauge a better understanding of these technologies it is necessary to provide detailed descriptions and potential uses for these technologies within the value chain.

Information, idea generation and design

Design is a primary indicator of the cultural, technological, social and economic standing of any nation so it therefore represents a significant technological and skill investment which is critical to sustaining a high quality world manufacturing industry. The importance of design in adding value to manufactured goods, improving export performance, developing elaborately transformed manufactures and succeeding in niche markets cannot be underestimated. Therefore the importance of design should be reflected in programmes for cultural, industry, regional and urban development.

At this stage the artisan requires information about the consumer’s preferences and has a need to receive orders. In order to do this the artisan requires information, accessibility to this information, ability to communicate locally as well as integrate with international designers. Thereafter he/she also requires the capabilities to pick up these orders. From a technological point of view the solutions that will have a high impact on these processes are Human Language Technologies as well as Mobile and Wireless technologies.

These technologies will allow the bringing of information to all citizens in their respective languages (the conglomeration of these technologies provide possibilities of speech recognition and language translation), an informed and fully information inclusive population, knowledge empowerment, cultural and language diversity, skills transfer, development, training and education as well as market intelligence. Thereby the manufacturers will be able to have an understanding of what the consumer necessitates.

Apart from ICT to enable communication and information there is a need to focus on product technologies as well, doing so enables an improvement for these products.

Human Language Technologies

These consist of technologies that use knowledge about spoken and written language and about developing computer software to recognize, analyse, interpret and generate language (Lackwood and Joscelyne 2003). Some of the technologies that are used here are speech recognition, speech synthesis, language translation technology and spoken language.

This technology is an enabling technology which can address the situation of information empowerment and allows people to interact with technology in a natural fashion. It undertakes to solve various issues like illiteracy, language barriers and disability. It also allows information to be provided in technologically underutilised regions of the country (CSIR, 2004). HLT can enable seamless human-computer interaction - both spoken and written – which improves efficiency as well as user-friendliness.

HLT Bridges the gap between computer literacy and availability of information to all. The speech technology can be utilised for interaction with various databases of information and it can be accessed through various means like telephone, information kiosks and the internet.

In terms of industry linkages it has the potential to facilitate government service delivery, stimulate economic activity, enhance cultural tourism and improve the cultural industries by having an accessible multilingual technology.

Resource development is a very important requirement as well as additional research and development. The deployment of the various technologies is necessary as well as having a storage capacity for a massive information load.

Mobile and wireless technologies

In order to bridge the digital divide mobile and wireless technologies are very important for the communities in remote areas. Rural communities experience difficulties in accessing support services. This poor access is due to lack of interfacing mechanisms and methods of communication between public sector service providers and the craft producers.

Product technology

Quality is a competitive advantage therefore an improvement in the product will result in a better quality manufactured good from the foundation of the value chain process. By a combination of traditional and modern product development approaches as well as innovative techniques craft products can be produced that will capture local heritage as well as local cultural knowledge.

In order for the improvement of the product to occur there are certain attributes that need to be taken into consideration the improvement with the design of the product is one of the more important attributes. Therefore in order to have the ability to establish a strong link between the arts and other areas of production, better use of design skills and improving the design of the products are important. These improvements can be done through utilising better tools, using international designers that transfer their skills onto the local market.

The use of specialised design software like CAD is becoming a feature of the design process and crafts and design students should be increasingly trained in its use. The increased use of hardware and software and its constant metamorphosis is making the use easier, thereby resulting in computers becoming more important and viable for designers and crafts makers.

The requirements in order to increasingly develop these product technologies are an investment in research and development competencies and create facilities within a network of design centres of excellence, establish knowledge repositories on traditional products and process technologies; this will improve skill transfer and capture the local cultural heritage, as well as knowledge from master crafters.

The type of product technologies that could be useful in developing better quality products should not include very high extraordinary technologies but rather simplistic innovative solutions to the technologies that are already in existence:

Ceramic/pottery products

- Improving the quality of materials and firing processes
- Better moulding processes as a substitute for coiling in the ceramic process
- Testing methodologies for ceramic materials
- Potting wheel to reduce non-value-added physical effort in pottery production
- Improvement of the quality of materials and firing processes for ceramic/pottery products

By using an innovative solution (provision of a better type of insulation material) during the firing process of the pottery products, will enable the temperature to go up higher and provide a better quality type of pot that won't break as easily.

Other products

- Development of drying and storage processes for wood products
- Technology development for testing of different chemical dies and colours for reeds and grass
- New product technology applications
- Appropriate equipment, sensing technologies like solar technologies (solar sewing machine)
- Computerisation
- 3D technology software packages/systems that integrate both artistic and engineering capabilities

Production

Production technologies

To remain a globally competitive art and craft industry there needs to be value creation within the value chain. By using production technologies it will enable the improvement of labour productivity in a very labour intensive as well as price competitive environment and industry. The cultural value of the products within their commercial value context cannot be compromised. Low cost production methods are very important to sustain small businesses within this industry

- The types of production systems that are available and applicable for South Africa were identified within the Advanced Manufacturing Strategy and it is appropriate to include them for a sustainable sector namely sequential production which enables a greater operator accountability for quality and costs of products; lean manufacturing which eliminates waste of oversupply, ineffective delays, unnecessary process applications, defects and illogical material flows as well as agile manufacturing which creates rapid prototyping and reverse engineering technologies, it also increases customised production of low volume and high quality as well as value.

Advanced Materials Technology

Research has been done by various organisations including the CSIR into technologies and local craft products can be improved through innovative and new material combinations which supplement the innovation of the product technologies. Using advanced materials an improvement of product quality in terms of reliability and durability can be made with a combination of modern advanced and home-grown techniques as well as methodologies.

The cultural value of the product has to be maintained but understandings of the material process specifications as well as reactions are done through the various appropriate testing methods.

Advanced materials for textile-based craft

In utilising advanced materials technology it will allow a combination of new and innovative materials that will enhance the properties of the existing product as well as allow opportunity for developing recycled materials.

When applying advanced materials technology it will allow improvements in the product's quality in terms of reliability as well as durability, local craft products will also be differentiated through the use of new material combinations. The requirements to enable the use of advanced materials in improving the arts and craft sector is to develop advanced materials for textile-based craft and also introduce smart materials, high performance textiles, composite textiles and biodegradable textiles. Natural fibres should also be utilised effectively.

Advanced materials for preservation of wood

Wooden objects are an important part of the arts and culture section therefore the treatment and conservation of painted wooden objects are important. The treatment mostly considered as interventions are subdivided into two big groups namely cleaning and fixing or otherwise known as consolidation.

Materials used in these treatments can be placed into generalised groups, cleaning mixtures and synthetic polymers

Cleaning mixtures and Synthetic Polymers in the Conservation of Painted Wooden Objects

An important point is to select chemicals, i.e. cleaning mixtures and polymers for which the useful properties have been thoroughly tested. The choice of a material for conservation of a particular object must be made after consideration of the properties required for the material in situation, the method of application and the method of removal.

Cleaning mixtures

Last 10 years the utilisation of the newest solvents and mixtures has not been as quick as polymers. In addition to "traditional" solvents only few new recipes have been used. As traditional mixtures Turpentine, Ethanol, Ethyl acetate, Propanol, etc. can be used. A few years ago very strong solvents like DMF (Dimethylformamide) and Cellosolve (2-Ethoxyethanol) were used but as the new cleaning mixtures, some solvent gels and solutions, where the active component is surfactant can be named.

Polymers and possible applications in the conservation of painted wooden

Natural and synthetic polymers have always been used in objects as adhesives, consolidants and coatings. Previously mostly natural products such as dammar, mastic, beeswax, fish glue, etc. were used for these purposes. But now a lot of synthetic polymers are available.

In conservation of painted wooden objects five polymer groups have been identified.

1. Vinyl acetate derived polymers
2. Acrylic polymers
3. Polyethers
4. Polymers derived from cellulose (used before by paper conservators)
5. Polymer from the group of tertiary amides.

Consolidation of wood with polymers

Consolidation is needed then wooden objects are so weak that they are not possible to exhibit, use, transport etc. Consolidation is irreversible, so in this process there is need to use materials of proven stability. The minimum (optimum) amount of consolidant should be incorporated in an object. Examples of these include vinyl acetate derived polymers, acrylic polymers and polyethers but natural materials, a mixture of wax and resin have and can also be used as a consolidant.

Cleaner production processes

Cleaner Production is the continuous application of an integrated preventive environmental strategy to processes, products, and services to increase overall efficiency, and reduce risks to humans and the environment. Cleaner Production can be applied to the processes used in any industry, to products themselves and to various services provided in society

For production processes, Cleaner Production results from one or a combination of conserving raw materials, water and energy; eliminating toxic and dangerous raw materials; and reducing the quantity and toxicity of all emissions and wastes at source during the production process. (UNEP, 2002)

For products, Cleaner Production aims to reduce the environmental, health and safety impacts of products over their entire life cycles, from raw materials extraction, through manufacturing and use, to the 'ultimate' disposal of the product.

Cleaner Production is a ‘win–win’ strategy because it protects the environment, the consumer and the worker while also improving industrial efficiency, profitability and competitiveness.

Cleaner Production can be especially beneficial to developing countries and those undergoing economic transition. It provides industries in these countries with an opportunity to ‘leapfrog’ those more established industries elsewhere that are saddled with costly pollution control.

Distribution

Supply Chain Management

In its most developed stage Supply Chain Management (SCM) is the oversight of materials, information, and finances as they move in a process from supplier to manufacturer to wholesaler to retailer to consumer. It is said that the ultimate goal of any effective supply chain management system is to reduce inventory (with the assumption that products are available when needed). As a solution for successful supply chain management, sophisticated software systems with Web interfaces are necessary or web service providers that provide part or all of the Supply Chain Management.

Increasing numbers of companies are turning to Web sites and Web-based applications as part of the SCM solution. A number of major Web sites offer e-procurement marketplaces where manufacturers within the arts and culture industry can trade and even make auction bids with suppliers therefore this will be extremely useful in marketing products and selling them off more efficiently.

In the cultural sectors scenario basic supply chain management is necessary where things like electronic catalogue, on line ordering can be used. The key enabler within this domain is the internet.

Marketing

Internet Technologies

The greatest impact on the sector are online marketing tools consisting of e-commerce, internet and other such technologies which will enable access to international as well as local end-consumers. The Internet is rapidly becoming an effective and efficient means of communication and marketing for crafts-makers.

The internet industry is characterised by rapid development of content over computer networks. The rapid pace of the internet has resulted in intense competition for web audience attention and users of internet software. The internet industry encompasses all companies engaged in creating, developing or processing electronic information through a computer network system.

Many of these companies are as a direct consequence of the computer software industry. Though the internet is not new, growth of this industry has taken off in the past few years due to the commercialisation of the World Wide Web. The World Wide Web allows publishers to create electronic publications with text graphics, pictures, data, voice and video. Since the internet involves no real barriers to creating publications, virtually anybody can create information and distribute it over a computer server.

As the number of online users grows, and as the speed in which people connect increases, the online marketer will have many more tools available.

People who are online are starting to connect using faster "broadband" connections. This allows for easy video and audio access. Currently, the majority of online users are not connected at a rate fast enough for convenient downloads of a large nature. But when the number of high-speed users grows, and it will, the Internet will take on the look of an interactive cable-type television with millions of channels.

Internet Technology Applications include E-commerce, online Stock Trading, online Travel Industry, and online education which is good for allowing the products to be made known globally as well as encourage cultural skills transfer. Very soon a practical means of selling will be "live" customer service, where a consumer can watch a supplier in his/her place and then actually order from the shelf; or perhaps place an order for a "work in progress"; the particular situation and needs will have to be taken into consideration

Portal for industry hosting

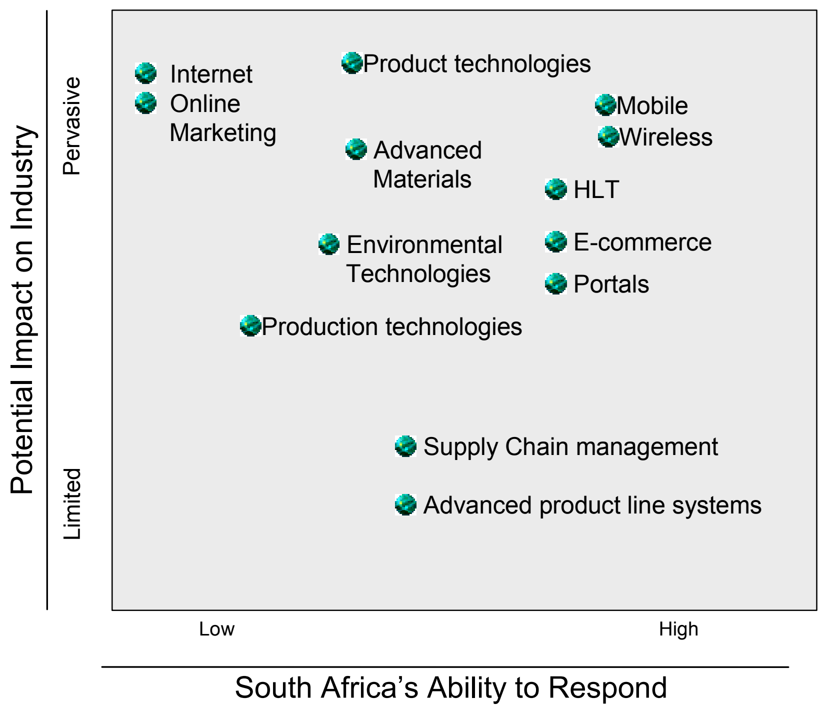
- industry database of locations and products
- expertise, econometrics, policy and regulations

A key barrier to e-commerce is the fact that buyers are accustomed to touch and look at physical three-dimensional objects. Three-dimensional image technology, although available, is still expensive and not yet fully accessible to most internet users.

10.6 Conclusion

There are a wide variety of technologies to support the cultural industry but given South Africa's unique situation and objectives to create jobs, improve the quality of life, to have economical growth as well as be an all inclusive information society, the table below summarises the key supporting technologies which are necessary to sustain and grow the industry.

Figure 22: Impact analysis grid



Some of the important technologies that will enable the cultural industry to be a sustainable sector include advanced materials to improve the quality of the cultural products, mobile/wireless technologies which will provide the foundation for communication and ability to gather information in terms of consumer preferences, suppliers and designs.

The greatest impact on the sector are online marketing tools consisting of e-commerce, internet and other such technologies which will enable access to international as well as local end-consumers

The Internet is rapidly becoming an effective and efficient means of communication and marketing for crafts-makers. But it is positioned at the top left hand side of the positioning grid. For South Africa to take advantage of the internet as a means to market the products and services it will require an increased broadband capacity, better infrastructure and content provision as well as service provision.

Some of the means to optimally utilise the internet are designing of websites that are dedicated to developing and promoting the sector. These websites should include virtual crafts fairs, providing e-commerce for crafts in general and specific sectors, for example, beadwork, ceramics, glass, jewellery, textiles and woodcrafts. These sites should also contain chat-rooms, which offer the opportunities to promote and advertise craft products as well as the services that are provided by the artist. Individual makers can use the internet as a means to publicise and sell their work.

10.7 International Case Studies on the Cultural Sector

Economical data for the arts and crafts sector is not readily available it is therefore difficult to make an assessment of the size of the global market for arts and crafts. This has however not stopped continued promotion and development of the sector by governments and development agencies because of the benefits to the sector like job creation and ability to grow the sector using high labour and being reasonably low technology oriented. Developed countries as in other industries dominate the trade in the international arena of this industry.

There are currently government support programmes and incentives available for SMME development. However, according to cultural industry experts within South Africa, there is a significant problem of a limited access to this industry by a large part of the population because there is a lack of the ability to be able to comply with policies and regulations.

The following provides international case studies of three countries namely India, Australia and Scotland that have a powerful cultural industry sector. Some background information will be provided regarding their sector and also the lessons that can be learnt from them in order to develop our industry further, in terms of the way their sector is structured as well as governmental support.

10.7.1 India

The suppliers of arts and crafts include the developed, developing and the centrally planned economy countries. The developed countries predominantly specialise in the production and supply of machine-made substitutes which look similar to handmade arts and craft products. The developed countries account for the suppliers, while the remaining of the imports originates mainly from the developing countries and to a limited extent from the socialist countries. However, amongst the developing countries, India emerged as the third largest supplier of arts and crafts after Hong Kong and Taiwan; India has a very prominent cultural industry and has really done well to develop this sector further.

Based on India’s classification, the market for arts and crafts (including the machine made substitutes) is broadly segmented into two sectors, namely:

- Market for utility and utility-cum-decorative items
- Market for articrafts, i.e. crafts of purely decorative and artistic nature. However, the utility and utility-cum-decorative segment is much larger, compared to the segment for articrafts which is limited.

This segment is dominated by the importer-wholesalers, who normally import and distribute arts and crafts to retailers, department stores, boutique shops, specialty stores, etc. They work on a margin of about 50 percent on the landed cost while the retailer's margin varies from 100 percent to 200 percent on the wholesale price. Generally the importers in this segment expect their suppliers to be capable of effecting bulk supply of arts and crafts at standardised quality, finish and price. Their expectation is based on their experience with some of the South East Asian suppliers like Hong Kong, Taiwan and South Korea who have arranged bulk supply of selected arts and crafts by mechanising their arts and craft workshops without compromising the hand and artwork involved in the products to cope with the growing requirements of the developed country markets.

Arts and crafts industry in India

In India, the office of the Development Commissioner for Arts and crafts in the Ministry of Textiles group arts and crafts into the following categories:

- Carpets
- Art metal-wares
- Wood wares
- Hand printed textiles and scarves
- Hand knitted and embroidered goods
- Shawls as art ware
- Zari and Zari goods
- Imitation jewellery
- Miscellaneous goods

The Arts and crafts sector is one of the best performers among the thrust products identified by the Government of India for export promotion and growth. This sector, besides providing for the economic and social needs of the craftsmen, also play an important role in earning valuable foreign exchange for the country. In view of this encouraging performance on the export front, the share of this sector in all-India exports has increased. Besides earning valuable foreign exchange, this sector has been instrumental in generating employment and the much needed supplementary income for the artisans, particularly in rural areas.

In a country like India where rural development is considered a national priority, the arts and crafts sector, has started to play an increasingly important role in earning valuable foreign exchange for the country, as well as meeting the economic and socio-religious needs of the craftsmen and the community at large.

The arts and crafts industry is highly orientated with being labour intensive and provides employment to more than 2 million artisans and sustenance to their dependents (approximately 3 million). These artisans are mostly unorganised and in certain crafts, they only work on a part-time basis. However, most artisans are renowned worldwide for their artistic and traditional style, skilled craftsmanship and versatility. The Indian arts and crafts sector specialises in manufacturing and exporting impressive and wide range arts and crafts to the world market.

Export prospects

India is one of the major suppliers of arts and crafts to the world market particularly as the market for utility and utility-cum-decorative items, has been growing in size and importance. The overseas buyers in this segment of the market require volume supplies to be standardised in quality, finish and price. The novelty sector is growing faster than the traditional sector of the market. Although arts and craft exports appear to be sizeable, India's share in world imports is minimal. Despite the existence of a fairly large production base and vast reservoir of artisans, India has not been able to cash in on these opportunities. This is mainly due to the following reasons:

- The production and supply have continued to be inadequate
- The quality and finish are not standardised
- Subject to a given quality the price standard is not maintained
- The product development is not well conceived and effected
- Marketing and financial support to craft producers continue to be inadequate

SWOT analysis of arts and crafts export in India

Strengths

- India's art and craftsmanship is considered to be the best in the world
- Abundant skilled labour in the industry
- Raw materials for most arts and crafts are available locally
- Possess a variety of crafts ranging from art metal-ware to bamboo and jute products

Weaknesses • Usage of poor inputs such as Azo dyes in textiles and cadmium instead of silver • Areas of production lack adequate infrastructure • Exporters - ambiguity in nomenclature to avail duty drawback schemes • Artisans - lack of innovation and training • Packaging - not to international satisfaction.
Opportunities • Wave of oriental fashion • Eco-friendly goods are becoming popular • Great potential for partnering with large retail chains • Tourism being seen as a vehicle of growth • Networking with the Indian Diaspora
Threats • Issues concerning child labour • Competition from far eastern countries • Competitors engaging in mass produced goods • Non-tariff barriers • Major problem areas faced by arts and craft exports

In this sector, a more pragmatic approach in planning and management is called for. In this exercise, there is a complete co-ordination between the exporting community and the Government agencies. Some of the important factors in the marketing of arts and crafts are price, quality and delivery schedules. While prices are an important decisive factor, in terms of competition, quality of the product and its timely supply to the buyers and its presentation are also important.

India is one of the important suppliers of arts and crafts to the world market. Despite the existence of production base and the large number of craftsmen, India has not been able to take advantage of the existing opportunities. It is generally stated that this is mainly due to the following reasons:

- Infrastructure: The major crafts concentration areas have problems of infrastructure. The delivery schedule cannot be maintained due to transport bottlenecks, power shortages and lack of proper port facilities etc.

- Non-availability of raw materials: The production and supply continue to be inadequate due to non-availability of raw materials for some of the important crafts.

- Poor quality: The quality and finish are not up to standard due to non-availability of seasoning plants for wood and treatment of materials used for various crafts.

- Product development: Product development is not fully conceived

- Marketing: Marketing has been a major hurdle for Small Scale enterprises, its intensity varying from industry to industry and enterprise to enterprise. The problem areas have been broadly classified on the basis of views expressed by various exporters who were interviewed from the Arts and crafts Sector.

- The ability to identify a suitable product with marketing acceptability and good growth prospects

- Lack of finances

- Lack of proper infrastructure facilities

- Poor knowledge of marketing strategies, accurate market intelligence

- Inability to get adequate advertising and publicity

- Lack of understanding distribution channels

- Inability to provide credit facilities to customers

  - Less significance attached to modern methods of packaging, less emphasis on after-sales services

  - Artificial barriers in the market place in the form of inter-regional tax variations such as entry tax, sales tax, etc.

  - Excessive delay in payments made by Government Department and parent units in terms of ancillarisation

  - Lack of trained marketing staff hence an inability to push sales

  - Vulnerability in terms of dependence on large enterprises / marketing agencies

Steps for improvement

Marketing-oriented financial assistance: Finance is an area which small scale units reported as a major impediment for marketing. The credit extended by the units to their customers, to the trade and Government Departments and public sector enterprises, impedes the majority of their funds. It is, therefore, suggested that banks finance advertisement or promotion activities of products or assist with setting up of regional marketing offices.

Factoring services by the banks are given more priority. Factoring has been defined as a continuing relationship between a financial institution (the factor) and a business concern (the client); selling goods or providing services to trade customers on an open account basis.

The factor purchases the client's book debts either with or without recourse to the client and in relation thereto, controls the credit extended to customers and administers the sales ledger. In addition to purchasing of the book, the factor provides three basic services to the clients:

1. Immediate advance cash ranging between 80 to 90 percent against invoices whenever the client so desires

2. Credit management and administration of a sales ledger

3. Credit protection

The small scale units often report delay in receiving payments from both public and private sector units as well as from Government Departments. While legislation has been enacted (Delayed Payments Act) and the government has decided to set up tribunals in the states to deal with such cases, the same needs to be implemented expeditiously and effectively.

Special marketing grants similar to the Technology Development Fund being operated by Small Industrial Development Bank of India (SIDBI) are to be introduced.

Appraisal of projects : Projects of small entrepreneurs are scrutinised at the time of financing by State Financial Corporations and banks. Such evaluations are mainly from technical and financial points of view with minimum consideration of marketing. Entrepreneurs engaged in exports of arts and crafts indicated that for this purpose, marketing experts need to be engaged, advising entrepreneurs how to make their plans more realistic. Banks can also act as consultants to small scale units and guide them in formulating strategic marketing plans. Officers dealing with small entrepreneurs should be trained in all aspects including marketing management.

Infrastructural support: In the developed countries a strong factor contributing to small industry development has been the linkage between large and small enterprises. A two-pronged strategy is adopted, that is, development of infrastructure and improving the competitive strength of the industries. Success of industrial clusters has been demonstrated in the Indian context through development of townships such as TISCO. It was suggested that an Industrial Plaza in each major industrial cluster in the form of a multi-storeyed building be established. Each of these buildings are to include the following facilities:

- Wholesale market : The purpose is to make available high quality raw material, technology (equipment, plant and machinery)
- Clearing / forwarding agents and a truck / transport area
- Common display areas, exhibition centre
- Conference facilities and convention centres
- Office of District Industries Centre
- Banks
- Post Office
- Single or two starred hotels, restaurants
- Chamber of Commerce of the district
- Dispensary
- Suppliers' representative offices
- Consultancy outfits / training centre
- Data bank / computer centre

Training of entrepreneurs: Marketing is a specialised skill for which entrepreneurs should be given adequate training. Some organisations rendering training to entrepreneurs include the PHD Chamber in collaboration with Konrad Adeneur Foundation of Germany; Indian Institute of Management, Ahmedabad and National Institute of Entrepreneurship and Small Business Development (NIESBUD). A central level educational institution is given the responsibility to design short-term courses on specific aspects of marketing and other management aspects. These courses may be translated into various languages and are disseminated through SISIs, DICs, Industry Associations, and the Chamber of Commerce etc. The UGC television programmes could be used as a specific thrust on imparting education to entrepreneurs on marketing. These programmes are publicised during prime TV programmes so as to generate awareness regarding the timings / purpose etc. The training programmes for marketing are given special significance on Total Quality Management (TQM) and packaging aspects.

Wider publicity to government - The various government schemes outlined earlier are publicised through industry associations, Chambers of Commerce, electronic and print media.

Marketing companies: The government and financial institutions have taken steps to encourage private marketing companies by way of recognising them as small scale enterprises and providing institutional credit facilities for the necessary infrastructure and purchase of goods.

Sub-contracting: In India, there is no separate policy for the sub contractors. The policy related to small and ancillary units apply even to sub contractors belonging to SSI units. The new thrust of the government to encourage sub contracting activities in the private sector through grants to industry associations for setting up sub contracting exchange is indeed a welcome step. In order to encourage sub contracting, it is suggested that multiple taxation on sub contracted items should be avoided by adopting a uniform rate structure for the sub contracting units.

Air travel for business purposes: Small entrepreneurs are given concessional rates for air travel abroad for business purposes.

What India is doing to develop the sector?

Policy Level measures

Recognition of the sector as an industry: There is a strong need to recognise the Arts and crafts Sector as a full-fledged industry so that this sector can avail the benefits accrued to an industry.

Diversification of cultural export base: Attempts should be made to diversify the cultural base to various countries by exporting various Arts and crafts items which are the symbol of the Indian culture.

Adapting cultural goods to international trends: With the advent of globalisation, the world has become so small that the market as a whole has shrunk. While designing the product, the marketer senses the needs of the customer across borders and changes it in the form that is readily accepted.. International trends have to be kept in mind before manufacturing products for the export purpose.

International promotion of India's cultural artefacts: The promotion of India's cultural artefacts is done internationally in order to provide a feel of the Indian products.

Joint ventures for technological, marketing and financial strength - Companies enter into joint ventures with other companies in the same trade as this helps them to synergise their efforts with each other and thus building mutually benefited relationships.

Enterprise level measures

Customer focus: Customer is the king; the organisation focuses on the customer's need and choices before manufacturing the product.

Engagement of services of designers: Tastes and fashions change at such a rapid pace that it becomes difficult to keep up with it. In order to offer the customer something unique, various designers are engaged by to get benefited by his skills and at the same time reap the benefits of attracting customer's attention.

Use of dyes and moulds for standardisation: Dyes and moulds which are required for standardisation in the Arts and crafts Sector should be used by the exporters to be compliant with the norms of the Industry.

Specialisation: Arts and craft Exporters specialise in one field, making it their core competence and hence benefiting financially from their expertise in the area

Development of specialised ancillary units: Specialised ancillary units are developed more

Packaging: Packaging is an important part of the P's of the marketing mix. Exporters place great emphasis on choosing a suitable package for the product so that the customer is attracted towards buying the product

Quality certification: The products manufactured should be compliant of the various quality certifications in order to ensure an industry quality standard

Participation in International fairs: Artisans participate in International fairs and keep themselves abreast on new trends in the market, thereby understanding the requirements of people abroad.

Branding of arts and crafts: In today's competitive world, it is imperative to create an image of the organisation’s product, differentiating it from the competition.

Lessons learnt from India

The Indian Arts and craft Industry has been faced with great competition since the opening of the economy. Although the share of the Indian arts and crafts is very small in the World trade of Arts and crafts, Indian Arts and crafts have been successfully able to make a mark.

The export potential of the Indian Arts and craft Industry can be rightly judged with the kind of efforts that the Indian exporters are putting in. They are continuously working on their strengths of price leaderships, good quality and new and innovative designs. Simultaneously, efforts are being made to overcome their weaknesses and to cash in on their opportunities.

The government is keen to improve the status of the industry by providing facilities in terms of infrastructure and reduce taxes. There is a great export potential of the Indian Arts and crafts.

The government provides extensive support for the village industries through a variety of schemes like the Khadi and Village Industry Commission.

There is a complete co-ordination between the exporting community and the Government agencies. While prices are an important decisive factor, in terms of competition, quality of the product and its timely supply to the buyers and its presentation are one of the main issues that are focused on as being important.

Although India has constraints similar to South Africa they still seem to be doing well with being the third greatest exporters of their craft.

10.7.2 Australia

Australians are active participants in the cultural industries, with approximately 3.5 million people involved in some form of work in the sector. Of these participants, 1.3 million receive some form of payment for their work, while 2.2 million participate in a voluntary capacity. (Create Australia, 2001)

Western Australia (WA) has a potential comparative advantage in the Indian Ocean and Asian region. This is recognised by the agencies of the Culture and Arts portfolio. The cultural industry sector contributes in excess of $940 million to the State's economy each year.

Government contribution

Commonwealth, State and Territory government funding for cultural activities was $4,454.5 million in 2000-01. This represents an increase across the board of $398.1 million or 10% compared to the previous year's funding from the three-tiers of government. Funding for cultural activities represents approximately $231.11 per person which is an increase of around $18 per person since 1999-2000.

The Western Australian State Government is committed to supporting arts and cultural experiences in education, employment, business and trade, in raising the State's profile in the wider world and as a tool for countering isolation.

Western Australia exceeded the State and Territory average with $137.27 funded per person for cultural activities (including arts and heritage). Of the total amount of funding, the Western Australian State government allocated $260.4 million to funding arts and heritage activities during 2000-01. (Cultural Funding by Government 2000)

During 1999-2000 Western Australian arts authorities invested in arts and culture to a total of $86.2 million. Western Australian arts authorities and other authorities (other government agencies) investment in arts and culture combined totalled $178 million. Western Australia provided funding in 1999-2000 to Broadcasting and film totalling $3.22 per person, well above the national average of $2.21 per person. (Cultural Ministers Council SWG Cultural Funding in Australia Three Tiers of Government 1999-2000).

The State Government continues to implement its commitment to providing opportunities for Western Australians to actively participate in and attend arts and cultural activities in 2002/03.

The Environment

The State has an important built heritage and cultural environment to nurture, maintain and protect as well as its natural environment. Cultural diversity and bio-diversity are equally important. A major challenge for the State in addressing the degradation of the land, salinity, water and other issues is changing the culture and thinking of the community. The Western Australian Museum has an important role in contributing to Research and Development into environmental issues.

The Western Australian Government is committed to the process and concept of sustainability and to the establishment of sustainability partnerships with other levels of government, the community and industry. The arts and culture can be used to raise environmental awareness and reshape community practices, behaviours and values. This will foster the development of a proactive society that places as a key priority the value of its cultural and environmental future.

Government funding

ITOL

A Commonwealth Government funding programme administered by the National Office for the Information Economy (NOIE) designed to accelerate the national adoption of e-business solutions, especially by small to medium enterprises across a broad range of industry sectors and geographic regions including the cultural industry.

Small Grants for Small Rural Communities Programme

A small grants programme for small rural Australian communities will offer approximately $300,000 a year in grants to benefit people in rural and remote communities.

Small, well targeted grants can be useful to small rural and remote communities and to make small grants more accessible to communities in rural Australia have established this new and innovative funding programme.

The programme is generously supported by The RE Ross Trust, The Myer Foundation, The Pratt Foundation, The William Buckland Foundation, Perpetual Trustees and FRRR.

This collaborative approach is designed to:

- Improve targeted use of funds improving access for rural and regional communities
- Provide a simpler application process
- Enhance efficiency and effectiveness for philanthropic trusts and foundations who wish to support small communities

Currently, applications that support the following areas of interest are usually given preference:

- Community hardship in drought effected areas
- Technology and equipment
- Retention of young people in rural and regional Australia.
- Resettlement of immigrants in rural Australia

ANZ/FRRR Seeds of Renewal Programme.

Sustaining rural communities

The *Seeds of Renewal* small grants programme offers over $250,000 in grants to small, rural Australian communities.

Projects that are typically funded are projects that have a charitable purpose and contribute to development in social and community welfare, economic, environmental, health, education or cultural areas as well as applications from non-profit organisations with an ABN; and Communities that have a population of 15,000 people or less.

Rural Education Fund

The Rural Education Fund (REF) seeks to ensure that quality education remains accessible to children in rural and remote communities regardless of climatic and economic conditions.

Through collaboration with local agencies and sponsored partnerships with individuals and corporations, the REF will be able to extend the educational recourses and individualised learning support that rural students require.

Lotterywest

Lotterywest supports a wide variety of non-profit, community-based proposals that enhance the lives of Western Australians right across the State.

The grants programme is an investment, not only in the future of individual organisations, but in the future of the Western Australian community as a whole. Each year they provide close to $50 million to approximately 1,500 non-profit organisations and local government authorities.

Below are a few examples of organisations and projects that Lotterywest supports:

- Organisations working with particular target groups - the elderly, youth, children, Aboriginal people, people with a disability or those in crisis

- Indigenous and multicultural organisations
- Heritage and conservation projects
- Community legal centres
- Aboriginal corporations
- Playgroups
- Small cultural groups
- Refuges
- Employment services
- Local Government Authorities

Aboriginal Programmes and Business Support Services

Although Australia cannot be regarded as a developing country, it has also undertaken some innovative approaches to developing its cultural industry regarding the Aboriginal people:

“Stories of the Dreaming” is collaboration between Australia's Cultural Network (through the Federal Department of Communications, Information Technology and the Arts) and the Australian Museum. The stories originate from the cultures of Indigenous Australians and have been collected from all over Australia. They reflect an essential part of the life of Indigenous Australians. They also have the GSDC's Aboriginal Economic Development Unit which encourages Aboriginal economic and business development through its Assistance Programme.

Lessons learnt from Australia

There are a number of initiatives that Australia has available within the various states like Western Australia therefore a regional approach is conducted so as to maximise geographical closeness and cultural synergies.

10.7.3 Scotland

The Creative Industries contribute substantially to the Scottish economy. The Scottish Enterprise estimates that they support 100,000 jobs and contribute approximately £5 billion to the Scottish economy annually. They are set to grow significantly faster than the economy as a whole, and there is every indication that this trend will continue.

This contribution is a result of the following:

- Massive growth in the global infrastructure for rapid distribution of information and creative content

- The removal of barriers between industries through the digitisation of audio visual content which allows it to be more readily distributed on a global basis across different technology platforms, such as the Internet, digital television and broadband. New applications of technology which generate new cultural forms and new businesses, such as web and digital arts.

- The emergence of mass niche markets for content.

- The change in emphasis in computer use from processing users' own data to accessing pre-published content, usually with an interactive element.

Their success of the creative industries is also based upon the effective combination of creativity, enterprise and the application of new technologies. There are enormous opportunities for export earnings in the creative industries which can highlight Scotland's achievements in developing new forms of cultural expression internationally.

Scottish companies have carved out a niche in some of these global industries. Scottish Enterprise, Highlands and Islands Enterprise and the Scottish Arts Council are working together to support innovation in publishing and music. Scottish Enterprise is developing a strategy for supporting the creative industries. Future success depends upon the contribution of a vibrant and innovative cultural sector. The Glasgow Collection provides a good example of how partnerships between designers and manufacturers promote success.

Scotland's culture is dynamic and its capacity to respond to new influences and to integrate them with existing traditions has been an enduring strength. The ability to adopt and adapt, allied to a capacity for innovation, mean that Scotland is well placed to respond to the accelerating trend towards globalisation while maintaining a culture which remains modern, distinctive and relevant to the experience of the Scots.

The cultural and creative industries are one of the most significant parts of Scotland's economy: These industries also make a major contribution to people's quality of life. The key to their success in a highly competitive global market is quality. The Scottish Executive recognises the importance of creating the conditions to enable these dynamic and increasingly important industries to flourish.

Healthy participation rates in a range of voluntary arts activities demonstrate the commitment of individuals across Scotland to their communities. There is, however, scope to increase the number of participants and volunteers to ensure that the benefits are available to a wider range of communities.

It will be essential to ensure that the public support mechanisms for culture remain appropriate to the requirements of the 21st Century, make the best use of available resources, and provide appropriate leadership. They must operate to empower and enable individuals to engage, to experience and to realise their potential.

The existing support framework

The roles of the public sector include giving direct support to a framework of agencies, institutions and services which have become central to the cultural life of the nation. Scottish Executive agencies, such as Historic Scotland, carry remits for particular aspects of cultural provision and access, as do national institutions, such as the National Library of Scotland, the National Museums of Scotland and the National Galleries of Scotland. The Scottish Executive also funds the Scottish Arts Council, Scottish Screen and the Royal Fine Arts Commission. It sponsors a number of groups to support work in particular sectors and to establish supportive networks amongst the various contributors. These include the Scottish Museums Council and the Scottish Library and Information Council. Most of these bodies work at “arm's length”, making day to day operational and strategic decisions independently, but receiving funding from the Executive, to carry out an agreed plan for which they are accountable.

Being effective locally: the role of Local Government and authorities

Local authorities are key players in public sector cultural provision. Recently, structural changes have affected the way in which they are able to make provision. A range of new structures has developed to deliver new corporate objectives and many are involved in rationalising and restructuring to deliver a cohesive, corporate approach to services.

A number of Local Authorities have entered partnerships with one another, including the Scottish Arts Council, to support cultural activity.

Actions to enhance Scotland's creative industries

Work to promote the contribution of new technologies to the cultural life of Scotland, in partnership with Scottish Screen, the Scottish Arts Council and Scottish Enterprise and Highlands and Islands Enterprise

Work with the Department for Culture, Media and Sport (DCMS) to assure the contribution of the broadcast media to Scotland's cultural life, to include plans to capitalise upon the opportunities afforded by developments in digital technologies

Investigate the feasibility of building on existing work involving a range of bodies to establish a national product design network.

Lessons learnt from Scotland

Although Scotland has used high technologies to produce good quality products these products don't lose their cultural identity. It is very important to remember that South Africa has a sought after cultural heritage and phenomenon so efforts should be placed on creating products and services that are of high quality but the essence and cultural identity still remains.

10.7.4 Other examples of government interventions:

The Israeli government gauges the market demand by directly approaching the international markets. Thereafter product prototypes that are based on the stipulations of this international market are developed. Finished product prototypes are then given to the artists/crafters to produce a specified volume.

This type of intervention relates back to the initial value chain mention at the beginning of the report and would solve the issue of the crafters that are sitting with too many products as there is little or no demand for their products.

10.8 Conclusions for Sector Development

The cultural sector has the capacity to be both a source of the South African identity and also be a setting for the development of innovative activities that boost job creation. There is a growing correlation between culture and employment but it is however underestimated. The activities that have the best prospects are arts and crafts, heritage and activities linked to new technologies. The best way to develop this is by giving these issues the correct support and attention that it deserves.

The cultural field will constitute a range of activities that will encourage new technologies. Cultural reality is that the cultural industries need to be in accordance with present development of new technologies and also be in touch with the requirements and needs of the most significant socio-cultural movements.

As running a crafts business requires both artistic and business skills, one key issue for makers is the lack of knowledge and experience of administration and business management. This may constitute a significant barrier to entry into the market.

Therefore improved training opportunities in business skills and the management of resources are required as well as transfer of skills. As technology becomes an increasingly important means of communication and marketing for crafts-makers information, support and training in ICT skills should be made more available.

Professional crafts-makers need the resources and opportunities to conduct research to develop and improve their skills and experience.

The crafts sector would benefit from closer links with related industries. There are great similarities, for example, between textile crafts and the textile industry therefore the support for cross-industry working is needed to promote the development and expansion of the sector.

An important factor in the development of the sector is the quality of market information and of industry analysis. Crafts are a complex and fragmented sector which is difficult to define and classify. Improved knowledge of current and potential markets and of more effective ways to target them should greatly enhance the growth potential of the industry. This quality of market information will be able to be accessed through having entrance to technology platforms like mobile and wireless technologies as well as the internet.

CLOTHING AND TEXTILE SECTOR

11 TECHNOLOGY DEVELOPMENT TRENDS OF THE CLOTHING & TEXTILE SECTOR

11.1 The Clothing & Textiles Sector

The clothing and textiles sector comprises of three key focus areas:

- **Textiles**, manufactured fabrics and yarns from primary agricultural products and synthetic fibres
- **Clothing**, manufactured apparel from textiles, furs and leathers;
- **Footwear**, manufactured apparel from synthetic materials, textiles and leather.

The following diagram represents the structure of the industry:

Structure of Clothing & Textiles Sector in South Africa

Clothing & Textiles Sector

- Knitted and crocheted fabrics
- Wearing apparel except fur apparel
- Dressing & Dyeing of fur
- Tanning & Dressing of Leather; manufacture of luggage and handbags, saddlery and harness
- Footwear
- Spinning, weaving and finishing of textiles
- Other textiles

This sector has undergone rapid changes over the recent past. Until the 90's the sector was dominated by the Fashion industry but with trade liberalisation, the niche markets held by certain leading producers such as the US and western European countries (Italy and France) have been lost to cheaper exporters such as China and India. The "US Textiles Crisis" that started in 1997 as a result of the devaluation of Asian currencies marked the industry significantly.

The devaluation of these currencies meant that imports to those countries fell and their exports increased due to increased competitiveness. (International research, 2004a). Cheaper exporters took advantage of the opportunities the devaluation provided them and now dominate world textile production.

Furthermore, until the 70's the industry was dominated largely by a small offering of natural yarns and simple end-user products. Technological development in the 70's meant that the product offering in the industry was vastly broadened depleting the demand pool for natural fibres; and, the application of the new blends increased the demand for the more complex end-user products. Industry leaders in the Newly Industrialised Countries considered these trends and shifted production, technological capacity and production processes towards the latter, while traditional leaders in the industry focused on their established markets and products.

A significant factor in the demand side shift is related to human evolutionary changes. Not only are populations declining, but with relative income stability in the developed world, and western cultural expansion in the developing world, consumers are becoming more discerning therefore are creating broader spectrums of choice for diversified and differentiated lives and therefore products. This is further stimulated by the expansion of marketing of branded high-end goods. This is borne out by the relative growth in the branded high-end products globally (Jafta) – The undifferentiated mass market is indeed declining.

The changes in the sector are also attributed to the evolution of the industry. The shift away from natural fibres to synthetic fibres has placed new entrants in the market, particularly from the East at a comparative advantage (Jafta). This shift has been attributed to a number of critical factors (ibid.):

- Volatility of price in agricultural products, for example cotton.
- The lack of adaptability of natural fibres to mechanical advances in processing equipment
- Inability to package and store natural fibres and retain quality
- The lack of reliability of quality in natural yarns

Furthermore with technological advancement in the Textiles Industry towards value-added natural fibres and synthetic fibres the requirements of higher skilled workers increased. The industry in the established textile producing countries struggled to adapt to this new demand leading to a decrease in their output.

One on the most significant factors contributing to the shift in demand is that of technological development more broadly – other sectors such as aeronautics and automotive have created new demands on the textiles sector, such as sensory fabrics for seating comfort, resin-reinforced fabrics to replace metal components which creates lighter weight vehicles. The growing demand for intelligent and high performance textiles has created new opportunities in the Textiles Sector but industry in the established markets have been slow to respond to this demand. (International research)

Clothing & Textiles is one of South Africa's most important sectors both in terms of contribution to manufacturing and contribution to employment. The sector contributes 25 % of manufacturing output, and 2.8 % of GDP. The sector's export market is valued at R 2.43 Billion (negative trade balance), with imports valued at R 3.8 Billion. Until recently the sector had experienced year-on-year growth of 6.9 %; however 2003 growth figures were adversely affected by the strengthening of the South African Rand and the weakening of eastern currencies

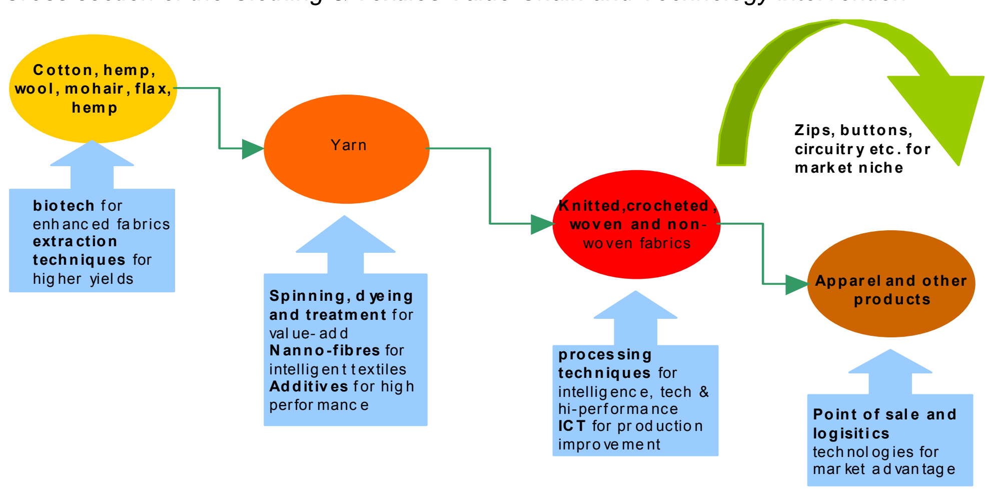
Opportunities offered by AGOA have mitigated the decline of the sector. Notably exports increased in 2001 by 62 %, through opportunities derived from AGOA, but overall this has failed to save the growing lack of competitiveness in the industry and the impact of the strengthening Rand South African textiles and clothing.

The sector employs 187 982 people in the formal sector but significant job losses have occurred since 2002 (estimated at 25 % of the formally employed in the sector). This recent downward trend for the industry n South Africa is unlikely to change.

11.2 South African Technology Trends

Although there are numerous threats and weaknesses in the South African Clothing & Textiles Sector, the diagram below demonstrates the potential areas of technology intervention to enhance opportunities in the sector. Many of the technologies reflected below are not applicable for the South African sector, however the discussion that is to proceed will demonstrate that there are clear areas of opportunity, still yet unexplored.

Cross section of the Clothing & Textiles Value Chain and Technology intervention



11.2.1 South Africa's Strengths in the Clothing & Textiles Sector

Increasing adherence to WCM

Although South Africa's Clothing and Textiles Sector is in crisis due to the factors identified above, one distinctive advantage South Africa offers is its increasing capacity to adhere to World Class Manufacturing (WCM) standards. With trade liberalisation, the competitive advantage offered by NIC producers will be eroded even though it may not adversely affect the dramatic lead these countries have in the sector. WCM will begin to play a much grater role in trade in the sector as the end of the Multi-Fibre Agreement looms. The implementation of mechanisms and processes that ensure WCM means that the investment required for the "passport to trade" for South Africa will be limited in comparison to other countries which have until now benefited from the lack of manufacturing standards regulation in the global market.

Globally competitive mass producers and niche producers

The Clothing & Textiles industry in South Africa has the advantage of being able to produce the simple products for the mass market; as well as the complex products for the high-end and high performance market. Historically South Africa has occupied an advantageous position in the natural fibres market. Value-addition in this sector is supported by strong technological development and leadership in the local industry. Recent political developments have exposed South African culture to the world and the growing interest in South African cultural products is an opportunity in the high-end and braded products segment. An ability to exploit advantages in both these markets is what will stabilise the Clothing and Textiles Sector in South Africa.

Strong trading relationships in developed world

With the implementation of AGOA and other similar trade initiatives, as well as the NEPAD initiative, the already established trading relationships South Africa has with the world will be strengthened. Furthermore South Africa's infrastructure and institutional advantages in relation to other African countries presents significant opportunities for trade, as protectionist policies decline with increasing trade liberalisation.

Rich in natural fibres (wool, cotton and mohair)

Given South Africa's advantageous position in the industry segment of natural fibres, and the growing trend towards their beneficiation, South Africa has an opportunity to position itself positively in the value-chain through value-added natural fibres. The health benefits of natural fibres suffer from a poor image globally but with changing consumer tastes towards environmentally friendly consumption patterns, the potential for value-added natural fibre segment is yet untapped.

Good infrastructure in technical support, telecoms and transport

A general point about South Africa's competitive advantage in the manufacturing sector is the country's strong transport and infrastructure capacity. As African trade opens up to the world, South Africa's infrastructure presents international traders with a portal to the continent and significant opportunity locally.

Low cost of electricity

South Africa's low cost of electricity is particularly significant in the Clothing & Textiles Sector which is a manufacturing driven sector With the sector requiring greater value-addition for competitiveness in the global market; processing and finished end-user products will dominate the industry locally. The role of electricity driven equipment in this shift is undoubted and its relative cost-efficiency places South Africa in a comparative advantage with its competitors.

11.2.2 South Africa's Weaknesses in the Clothing & Textiles Sector

High cost of labour and inflexible labour market

The South African Clothing and Textiles sector is highly unionised which inevitably leads to an increasing cost of labour. This, against the backdrop if the significantly cheaper cost of labour in the NIC's means that the input costs of the sector are uncompetitive. Furthermore other factors of production such as productivity and technology development are hampered by the volatility of the labour market.

In niche segments, high cost of finance and capital

Niche market products increasingly require advanced, R & D, plant and capital for commercialisation. In South Africa the cost of finance is relatively high which limits the profitability of the commercialised venture. The risks associated with high input costs may explain the tendency of the industry to avoid obvious niche opportunities in the global sector.

Lack of economies of scale

Given the nature of South African competitor's production capacity; and the dynamics of the global demand, South African companies are severely restricted in achieving economies of scale. The previous point reflects the high cost of capital in South Africa, which can only be offset when demand is significantly high and stable to justify the risk associated with capital investment. This is of particular concern in relation to AGOA and SAFTA where high demand exists but South African producers are unable to take advantage of this obvious opportunity, as they cannot produce to the scale required.

Rand volatility

The Clothing and Textiles Sector is one of the most price-sensitive industrial sectors in the global economy. The competitive advantage enjoyed by NIC's is low input costs and weak currencies making their products more attractive in the international market. means that the Rand's strength presents a barrier to trade.

Lack of adequate intellectual capital and innovation

Despite that fact that South Africa has significant intellectual capital in science and technology this has not been applied to technology development in the Clothing& Textiles Sector. This is largely attributed to the high levels of unionisation in the sector, therefore the threat of technology replacing workforce; as well as the high costs of capital for technology development in the sector (benchmarking study 2004). Given that economies of scale and profitability are limited, innovation is reprioritised.

Lack of advanced logistics management

Given the nature of the sector globally – demand for high value addition, mass production and the sensitive profitability ratios- logistics management does not meet the demands required by export-led growth in the sector. This is surprising since there have been major advancements in logistics management in the minerals, agro processing and automotive sectors.

Inability to compete in standard commodity and price sensitive segments

The South African Textiles Sector is dominated by standard commodity and price sensitive segments yet this is the segment of the industry where South Africa is least competitive. This is attributed to the high cost of labour, which is a critical factor of production in this segment.

Inability to graduate in value-chain to higher value-added markets

A range of factors contribute to the inability of the South African Clothing and Textiles Sector to take advantage of the opportunities higher up in the value-chain. Of note, the nature of labour in the industry, the high levels of risk associated with capital investment and the volatility of the export market all prevent South African manufacturers from entering the higher value-added segments. These structural weaknesses present a major challenge to the industry in going forward under increasing competitiveness pressures.

Lack of institutional support in export markets, particularly in SADC

A critical area where comparative advantage exists for the South African Clothing and Textiles sector is the market opportunities in SADC. Cheap eastern imports dominate the market amongst South Africa's neighbours. Proximity, preferential trading relationships and socio-economic development imperatives all make Southern African markets attractive to South Africa. The sector locally has yet to penetrate these markets largely because it lags behind in fostering appropriate trading regimes in the region.

11.2.3 Sector Specific S & T Focus and Activities in South Africa

A leading institution in technology development in the Sector is the CSIR's **Centre for Fibres Textiles & Clothing**. The centre operates in partnership with the Industry and is currently working 0on beneficiation of natural fibres as well as process optimisation technologies in the natural fibre beneficiation pipeline (CSIR 2004).

Trade& Investment South Africa (TISA) offers a support programme for industrial innovation where 50% of the direct costs of development are subsidised, provided the applicant could justify the patent/innovation/research is significant in technology terms and demonstrates commercial advantage of the product.

11.3 Global Technology Drivers

11.3.1 Work and lifestyle

There are a number of general trends that drive technology **W** development more broadly that must be noted in this discussion. The organisation of the workplace and its impact on lifestyle is a critical consideration. The Department of Science & Technology's Foresight Report (2001) identified the following general trends that will affect manufacturing in medium to long term (10 – 50 years):

- Service industries will dominate manufacturing
- Intellectual capital will dominate over resources (capital, land and labour)
- The information age and its components will penetrate all the facets of industrialism
- Organised labour will extend its prevalence making stakeholder management a key factor of production
- The flexibility and dynamism of small enterprises will replace the mega-organisation in the value-chain

For the Textiles Sector this means that greater emphasis will be placed on leaner production and smaller firms, research and development will play a greater role in the sector; and, ICT will be diffused to a greater degree in the sector.

11.3.2 Value Chain Management

The concept of value chain management seeks to optimise the value created at every stage of production through limiting value chain activities that do not make a significant contribution to profit or optimisation or vice-versa; identifying and eliminating wastage , leakages and seepage; lowering costs and price; increasing quality and output; and, enhancing service standards. It is anticipated that these drivers will increase reliance on information and communication technology, as well as people and leadership development in the workplace (Department of Arts, Culture, Science & Technology, 2001). **Product & Process Development**

Three key considerations are pertinent to this discussion in the product and process development sphere. As mentioned above, the flexible organisation and flexible production will prevail; Computer assisted processes and products will dominate; and resource management for environmental sustainability will be a critical competition factor.

11.3.3 Impact of the Cost of Labour

Historically the clothing and textiles industry has been labour intensive. Until the recent shift in human rights orientation as a factor for trading on the global market a number of countries dominated the sector with the comparative advantage of cheap labour. Although this factor is expected to change in the medium term, the market penetration achieved by NIC's especially, through low input costs (one critical factor being the cost of labour) has been consolidated and may not be reversed through human rights standardisation but may be, to a certain degree, underscored.

11.3.4 Trade Liberalisation

Trade liberalization will impact dramatically on the sector globally as by 2005 (phase-out of the Multi-fibre Agreement - Uruguay Round). Prevailing protectionist regimes will be removed providing a competitive environment for production. With a levelling of the playing fields in terms of input costs and trade regulations, textile-producing countries will seek out new avenues or beneficiation, potentially driving technology development towards niche markets and higher-end processed products.

11.3.5 The Impact of the Information Age

Technological advances, such as Internet and wireless technologies, that have eliminated the factor of distance in the export market, have enabled supplier linkages over vast distances. This has had the impact of emerging economies capturing a large proportion of European trade, previously dominated by the US

11.3.6 Trends Towards Greater Supply Chain Management

Supply chain enhancement is occupying greater focus from producers as casualization and sub-contracting begins to dominate the labour practice in the sector. Enhanced supply chain management creates a deflationary effect and therefore productivity improvements are being prioritised. In short the culture of work in the sector is being reorganised making the shop floor contested but also improving productivity.

11.3.7 Vulnerability of high-end branded products

High-end branded goods are facing increasing pressure from price-sensitive discounters. This creates a greater impetus towards guaranteeing quality and protecting brand names driving new technology developments in product traceability and identification.

11.3.8 Polarisation of the Clothing and Textiles Sector

According to David Rigby & Associates (1993) the Clothing & Textiles Sector globally is polarising in to two types of service. On the one hand, price sensitive producers export low-end poor quality mass-market goods such as Taiwan and China. High-end producers such as Japan and the US increasingly export high-quality high-end branded apparel and high performance and intelligent textiles. Producers across the globe must position themselves in these broad categories of products, taking into account their comparative advantage and internal capacity.

11.4 Technology Analysis

The following section provides a cross section analysis of four technology groupings and their applications, considering their relevance for the South African export market, and South Africa's capacity in the technology. This section will provide a descriptive analysis of the particular technology/grouping of technologies and make some preliminary comments on their potential impact.

11.4.1 Value-addition of natural fibres

South Africa is at a comparative advantage in the natural fibres segment of the Clothing & Textile Sector. South Africa is the largest Mohair producer in the world and already has strong trading relationships with European countries especially Italy. AGOA has produced a significantly higher demand for cotton. These developments in the trading regime present opportunities to maximise the demand for natural fibres and also require higher levels of quality output. As a result South Africa should enhance both its productivity in this area and the quality of its products.

Simply put value addition of natural fibres is the process by which natural fibres are augmented to produce superior quality. Specifically, the technology components include:

Testing systems for foreign fibres in Mohair and wool: These technologies assist with the identification of weaknesses in fibres, enabling categorisation and grading according to export standards. In the long term these systems identify genomic features that are predisposed to low or high durability.

Yarn formation; long and short staple systems: Given the diversification of products from Mohair, yarn demands in the global market are varied. Providing global importers with a variety of yarn products creates greater responsiveness to market trends in Mohair (and cotton to a limited degree) and therefore a competitive advantage.

Dying and finishing technologies: These technologies also focus on beneficiating raw materials and similarly provide for greater diversity in South Africa's natural fibre offerings. Particularly advanced, are those products benefiting from appli8cation of easy-care substances for easier handling and care such as crease-resistance, shrink resistance and colour consolidation.

A growing market globally is the market from plant fibres. Hemp, flax and similar products are in abundance in South Africa. **Processing of plant fibres** thus becomes a critical niche market that South Africa is in an opportunistic position to exploit.

11.4.2 Implications of new technologies for the South African industry

In order to meet the requirements of export markets the South African Clothing & Textiles sector will need to reorient its production structure toward machinery and systems that beneficiate natural products. At this stage producers are oriented toward processing volumes of natural products, unprocessed or processed to a limited degree. A move towards technology-oriented shop floors will require a new set of skills and competencies of workers. Give the high levels of unionisation in the sector and the current vulnerability of workers due to a decline in the profitability o the sector; a compact with the union movement could facilitate greater orientation towards beneficiation.

Greater linkages with supporting industries in the biochemical and biomedical sectors will need to be forged to create seamless production on the Clothing and Textiles Sector.

As has been mentioned, export markets will derive benefit from this reorientation but these markets much be researched and products must be responsive to export needs. This requires greater industry involvement in sector development so that market research, incentives and other interventions that promote market penetration are collective and shared in the industry.

Manufacturing by its nature has certain environmental impact. South Africa currently is leading in world class manufacturing standards compliance amongst developing world producers and new technologies in the cleaner production segment will need to be accessed to ensure that the comparative advantage is maintained.

11.4.3 High-performance and Technical Textiles

High performance and technical textiles are textiles made from synthetic and natural fibres that have been augmented with other substances to produce superior quality for use under adverse environmental conditions, in technical applicat6ions or for high performance activities

As with intelligent textiles, major applications exist in the health care field. New textiles in this category have relevance for wound care, tissue scaffolding and implants where organic products ar4 not available or unusable. Applications in the healthcare field also include prosthetics products for vascular repair/replacement and stents

High-performance and Technical textiles have the benefit of being applied in a wide variety of industries and applications:

This category of textiles also enhances the performance of parts in the **automotive and aeronautical** fields. Improvement of electronic devices, equipment and vehicle in term of their corrosion and weight performance through resin-enforced textiles is becoming a burgeoning market.

Protective fabrics for **disaster management and first responses teams** (Fire, chemicals, bio chemicals) are growing. Given the shif6ts in demand for military applications and disaster management more generally towards textiles that respond to extreme conditions, high-performance textiles are increasing in value.

Implications of new technology for the South African industry

Given that value addition natural fibres, and beneficiation of yarn is a significant opportunity for beneficiation in the South African textiles sector, it is expected that these technologies will have a high positive impact on exports.

The development of technical and high-performance textiles will facilitate the development of niche markets in the biomedical, disaster management, process optimisation, aeronautical and automotive sectors.

It is expected that these technologies will produce a range of new products for a variety of applications - which will have multi-sectoral benefits.

With greater utilisation of these textiles it is expected to replace materials currently used in biomedical, disaster management, aeronautical and automotive sectors, which poses a potential threat to conventional industries for components in these sectors, particularly metals and plastics.

Compliance with WCM requires new approaches to environmental impact from manufacturing so new products that limit metals content in production would place producers of technical textiles at a competitive advantage, as new applications would increase demand.

11.4.4 Information & Communication Technologies

ICT plays a significant role in enabling or improving manufacturing, the Clothing and Textiles sector is no exception. In this analysis we will be considering ICT technologies that positively affect time to market. Having said this there is a range of technologies in the ICT field that have other objectives such as cleaner production, and process optimisation. Our focus will be the former.

Affecting time to market is a fac6tor that requires broad industry collaboration. **ICT diffusion to develop connectivity** within the industry is critical in this respect. The Clothing and Textiles Sector is extremely fragment horizontally – among industry players- and vertically between management and the shop floor, which precludes industry collaboration from taking hold in an organic fashion. .

The lack of knowledge of a range of aspects – export needs, standards and opportunities, new technologies, mechanics etc – all limit industry collaboration in repositioning the sector. **A Portal or knowledge repository** for baseline data for the industry would significantly enhance not only sector collaboration but also productivity and performance, as individual enterprises would benefit from shared knowledge and skills, as well as responsiveness to export needs.

On the manufacturing side, the manual systems or entry-level automated systems are prevalent which limits competitiveness. Especially NIC's and our other competitors are vastly advanced in the use of manufacturing technologies **Tele-manufacturing technologies** optimise management of the production process and thereby increase productivity. Which will assist meet the demands of AGOA and SAFTA.

Advanced Enabling Systems, such as e-commerce, promote access to and penetration of markets, assist marketing ventures and market research, as well as share knowledge and resources The profitability of commercialised ventures will be enhanced through customisation, the mitigation of risk and enhancement of the production process. Increased export products and competitiveness in the market will be facilitated

Implications of new technologies for the South African industry

For ICT to be enabling in the production process, its reduction in time to market must be accompanied by greater responsiveness from the shop floor. This means that the workplace culture of the Mechanical Age will need to be reoriented to the just-in-time requirements of ICT. As mentioned previously this may raise discomfort on the shop floor and in an already fragile industry might require extensive relationship building horizontally and vertically to mitigate the discomfort created by ICT diffusion.

There is no doubt that ICT diffusion will generate new markets particularly those that require just-in-time production. Greater responsiveness to market demands and connectivity presents new opportunities in markets uncomfortable with the slow cycle of production that currently exists.

11.4.5 Intelligent Textiles

Intelligent textiles are the family of textiles that act automatically and/or intelligently. Based on recent developments in the field of artificial intelligence, intelligent textiles are a fast-growing sub sector and by their nature have significant industry applications.

Simply described, intelligent textiles are synthetic and natural fibres that are augmented with intelligent chemicals and computer circuitry to respond to certain environmental conditions and operational requirements.

There are numerous industry applications but the most notable include:

Patient monitoring is being largely being developed for chronically ill patients requiring constant monitoring of vitals such as heart rate, blood pressure, glycaemic levels etc. This will have numerous impacts. Patients subjected to in-patient monitoring will be able to be out patients and continue with living their lives without long periods in hospital. This also applies to people in the sporting arenas whose endurance levels can be monitored while participating in competitive or endurance sports, particularly under extreme conditions (heat, cold humidity etc).

The technology may also assist in **disaster management**, where critical loss conditions can be ascertained before emergency personnel reach the scene. This would assist emergency personnel target critical conditions and prepare adequately for rescue operations.

Of significance is the application of intelligent textiles in **automotive and aeronautical parts** that would assist the prevention of accidents and technical problems through the detection in changes in air pressure, temperature and other environmental factors.

Military applications are an important new development in the current political climate. As warfare is changing from traditional surface to air formations to an extensive array of ground orientated warfare and peacekeeping forms, enhancing military apparel with circuitry to assist communication is an obvious application for intelligent textiles

Although the research and development is in infancy there are indications that intelligent textiles will follow the life-cycle trends of other textiles and production processes to ensure compliance with environmental standards such as biodegradability and recycling.

Implications of development of intelligent textiles in the South African Industry

It goes without saying that intelligent textiles will provide a greater scope for new markets in the bio chemicals and chip circuitry sectors. Given the nature of the technology, R & D in this area will be focused on in countries that already have advanced biochemical and ICT capacity, still being nurtured in South Africa. New opportunities exist for integrating chips and digital bits into yarn. Countries with a competitive advantage in Yarn beneficiation will present a comparative advantage in this respect.

The field of intelligent textiles inevitably drives the development of niche markets. This has been identified as a critical success factor in the survival of the clothing and textiles globally, but more specifically in South Africa.

Intelligent Textiles are at the cutting edge f technology development and as such present interesting opportunities for lifecycle research in different material and their applicat5ions. Increasingly environmental protection is playing an important role in public policy across the world. The development of biodegradable and recyclable materials will not only be prioritised but will enhance the producer's compliance to WCM.

There is no doubt that intelligent textiles will play an important role in improving the quality of life of the world's people particularly in respect of medical applications. However it is anticipated that in its initial stages, the technology will be costly limiting its distribution in the developing world. While this is inevitable expansion into developing world markets will generate economies of scale for the technology ironically lowering costs. Commercialisation of the technology therefore becomes complex in the sense that its returns on investment are long-term – a necessary indicator of capital investment.

11.5 Technology Support For Sector Development

11.5.1 United States of America

Despite strong competition from South American and Asian producers, clothing and textiles remains one of the largest segments of the US economy. However the US Clothing & Textiles sector has suffered much of the same challenges faced by other established producers:

- Lack of competitiveness in the price sensitive mass produced markets due to a strong dollar, high input costs and low return on investment.
- Lack of industry vision and leadership to take risks in technology development so that alternative markets are accessed

In global terms the US represents 7% of global mill output and 18% of global textile consumption. Despite intense investment in sector development, Clothing and textiles is a weak growth sector with a negative growth rate (-9.7%)Employment in the sector has fallen from 2.2 Million formal jobs in 1985 to 714 000 in 2004. Since "US textiles crisis" in 1997, when Asian currencies devalued, production has fallen by 18 %, exports to Asia by 26% and exports to the EU by 27 %.

Due to the State's approach to intervention in the economy – that is a neo-liberal "hands-off" approach; sector development has been aligned to the lobbying process, rather than taken on a structural form. Few institutions exist to support sectors, with the exception of scientific research at academic institutions. However, the problem posed by this is that the research aspect of R & D is well constructed while the development or commercialisation path is limited. So, like South Africa the US has extensive academic research in the fields of sector development, but little commercialisation takes place of those technologies.

As mentioned in the previous discussion, sector development is institutionally and structurally embedded in the political process, where state congress representatives need to lobby for funding allocation through the earmark process. This prevents long-term investment in R & D and subject's innovation to the volatility of the political process.

The Main agency in textiles in the US is the National Textile Centre, The Centre comprises of a conglomerate of 8 Universities that act as a clearinghouse and facilitator for the industry. The NTC focuses its grant making and support towards technical and hi-tech fibres. Recent research has focuses on bioactive fibres, intelligent textiles and nano-composites.

Current science and technology focus of Clothing & Textiles in the USA

Whilst there is extensive industry based R & D taking place, this is not shared to ensure the competitiveness of firms and to protect their investment in R & D. As indicated earlier, government plays a very limited role in sector development, only through alignment with the political process.

The **National Textiles Centre** lobbies congress representatives to support technology development in different states on a state-by-state basis. The projects are identified through a [peer review process within the NTC and then it is up to the NTC leadership to lobby their congress representatives who in turn lobby congress for financial support of these projects. This process is not located within a broader sector development or industrial strategy, which suggests an inevitable lack of coherence. Through the funding pipeline, decisions for sector development are made on the whims of a few scientists or politicians. that potentially do not have the national interest in mind.

The **National Science Foundation Grants** support research and development of technologies or products that enhance global industrial competitiveness. The NSF is an independent foundation funded by the US government. Naturally its source of funding is linked to priorities on the political scale and determined on a term-by-term basis. Therefore medium to long term funding is not provided as the foundation must renegotiate its funding every political term as well as on n annual basis when budgets are negotiated. The result of this is that applicants ho benefit from this fund have other sources of funding and support for the primary research and testing phase of the product. This excludes a whole range of potential beneficiaries whose access to funds for the research part of R & D are limited, which in turn has the impact of overlooking innovation and technology development occurring organically on the sector.

11.5.2 Turkey

Turkey's Clothing and Textiles Sector is vertically integrated from yarn to finished products and is a significant sector in manufacturing in terms of GDP, employment and exports. The sector represents 10 % of GDP, 30 % of manufacturing and 20 % of employment. In Europe, Turkey has the most extensive textile manufacturing capacity focused largely on natural fibres such as cotton and wool. In synthetic fibres, Turkey is the world's 6^{th} largest producer. The sector is dominated by SME's except in yarn and fabric production, which are dominated by large companies.

The Customs Union agreement with the EU, in place since 1966, has adversely affected the Turkish Clothing and Textiles Sector as it has facilitated the growth of imports over exports. Further trade liberalization is expected to have a further negative impact on the sector.

In line with EU regulations, Turkey does not provide specific sector development support to the Textiles Industry. Rather the sector benefits from general incentives and industrial development support mechanisms that are permitted by the trade agreement with the EU. This leads to a largely unsupported sector, because the sector requires peculiar interventions in terms of global trends, and the general industrial incentives do not adequately leverage the industry towards competitiveness and growth.

Current science and technology focus of sector within the country

For reasons already mentioned and in some ways similar to the US case, Turkish sector development is very minimal. Of note, economic policy dictates that incentivising industrial development conflicts with trading relationships, in Turkey's case, EU restrictions, by creating comparative advantages considered to be unfair trading practices. However there are limited interventions noted below:

The **Turquality** Programme seeks to improve the image and receptability of Turkish products generally through subjecting applicants to quality assurance evaluations. In the event applicants receive the coveted turqaulity logo, the Turkish government may provide subsidies of up to US$ 500 000 for marketing and distribution; or US$ 300 000 for design and development.

The **Turkish Technology Development Fund** (TTGV) is a non-governmental agency with special status funded by the Turkish Treasury and the World Bank. The fund disburses R & D grants to industry generally with a specific focus on process optimisation and technical problem solving

TUBITAK (Scientific and Technical Research Council) allocates grants for long-term research and development that impact positively on industrial growth. The council takes a 20year view on technology investment providing an unusual opportunity for Turkey to develop beneficiation measures for the largely natural fibre industry. This is slightly different from the US case where funding is largely short to medium term.

11.6 Evaluation of SA Position & Concluding Remarks

In defining South Africa's positioning in relationship to this research a number of key considerations will be highlighted here:

1. South Africa's strengths & opportunities as well as weaknesses and threats
2. The global environment
3. The technology drivers
4. Identified technologies for future consideration
5. The International case study lessons

11.6.1 South Africa Strengths & Opportunities

The most compelling force in the South African Textiles Sector is the abundance of raw materials natural fibre (Wool, Cotton, Mohair, Hemp & Flax), as well as the market penetration of these products globally. A significant opportunity to beneficiate these products exists through increasing global demand for processed products from natural fibers.

Furthermore beneficiating of abundant natural yarns with biochemicals, circuitry and other substances that increase performance, technical applications and intelligence is fostered by South African science and technology endeavors in the country, the most notable, the Center for Fibers, Textiles and Clothing at the CSIR as well as the variety of industry-led interventions. South Africa has strong institutional capacity to drive technology development in these areas as well as proactive enabling mechanisms embedded in legislation. This "soft" environment is underpinned by world-class infrastructure and an overall competitiveness in input costs (the high cost of labor is offset by cheaper electricity).

This advantageous position is further strengthened by the trading relationships that have developed through AGOA, SAFTA and SADC. Although South African products are not adequately attuned to the needs of these markets, the opportunities are extensive and reorientation of the industry towards responsiveness to these markets enabled by government legislation and industry institutions. These advantageous trading relationships can be further entrenched through South Africa's increasing compliance with WCM, environmental standards as well as social standards and human rights requirements.

11.6.2 South Africa's Weaknesses and Threats

The most significant barrier to optimizing the Clothing & Textiles Sector performance is the inability of the sector to leverage its resources towards market needs. The sector has not been able to reorient itself away from raw materials extraction and mass-market production – where the Clothing and Textiles Industry in South Africa is least profitable and least competitive. This suggests a lack of leadership and vision within industry and a lack of coherence among industry players.

A number of interventions have been made to attempt to turn around the industry, reorient it towards the higher value-adding segments of the sector and increased beneficiation of raw materials. However due to extensive insecurity and risk aversion, industry players seem to prefer to "do what they know". In the medium term this will destroy the industry, as the current protectionist features of the economy will e eroded over time, making those producers more vulnerable to more competitive producers in the NIC's.

There are some structural barriers that need to be addressed before the "change of attitude" above can have an impact. First, while South Africa boasts world-class infrastructure, this is never adequately utilized, as logistics management capacity in the country is very limited. Second, the high cost of finance and capital for technology development is prohibitive and probably a contributing factor to the risk aversion of industry leaders.

11.6.3 The Global Environment

Two salient points must be noted in the conclusions on the global environment. First, the global industry is polarized into mass-market producers of low-end goods, and high-end niche producers. Evidently straddling these two poles in the industry has cost Turkey its competitiveness in the European market.

Second, the global environment is going to get more competitive with the phasing out of the Multi-Fibre Arrangement. Therefore the time in which to leverage on current competitiveness / market advantage is running out and any country hoping to position themselves in the Clothing & Textiles Sector globally, must make some fairly substantive strategic choices now.

Technology Drivers

The most significant technology driver noted in this discussion is the shift from the industrial age to the information age. This shift has not only impacted on the product offerings in high performance, intelligent and technical textiles but also reflects on the way the sector is structured, the role of the large organization and the nature of the shop floor and its relationships.

In addition, the changes in the socio-political landscape across the globe have driven demand for higher performance in warfare and disaster management.

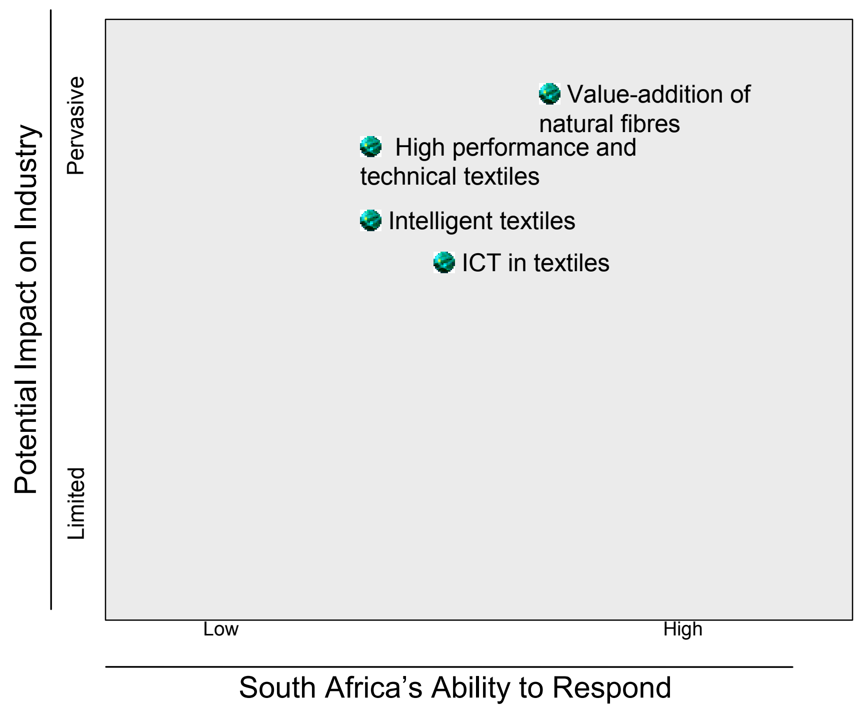
11.6.4 Technologies Identified for further Exploration/ Support

In line with the broad statements made in this section, the report places South Africa in high value-add section of the global textiles industry. This means that South Africa must optimize existing technology developments in the field and possible consider leveraging institutions to support beneficiation of natural fibers with these technologies. In brief the technologies are:

- Intelligent Textiles
- High-performance and Technical Textiles
- Value-Added Natural Fibers
- ICT for product and process improvement

The figure below shows the positioning and impact of the various technologies identified.

Figure 23: Impact analysis grid



11.7 International Case Study Lessons

The most salient lesson learnt from the international case studies is that in an environment of trade deregulation, and heightened competitiveness in the global market, technology development and its relevance for niche markets must be well-established. Both the US and Turkey followed a technology strategy after deregulation, which limited the impact technology could have on sector development. In short, the sector orientation and associated technologies must be embedded in the sector and the economy prior to deregulation to avoid committing what may be considered as “unfair competition” in deregulated markets.

AGRO-PROCESSING SECTOR

12 TECHNOLOGY DEVELOPMENT TRENDS IN THE AGRO-PROCESSING SECTOR

12.1 Summary

The convergence of several key industry trends has accelerated the pace of change in today's agro-processing industry. In response to declining profits, producers are developing new products with higher margins and functions, new uses for old products and waste streams, and incorporating cutting edge production technologies. Meanwhile, customer consumption habits are shifting and demanding new products such as organic produce and functional foods. On top of this, outside stakeholders, including government, are demanding an improvement to the environmental performance of the agriculture industry.

Food processing in all its various forms brings immeasurable benefits in terms of availability, shelf-life, and safety. This is important for safely feeding nations in which spoilage and other forms of damage and deterioration pose serious problems. Moreover, since processed products of all types retain their nutrients for an extended time, they are often the best way to provide countries experiencing chronic food shortages with an adequate supply of nutritious products.

The following list summarizes the important research and technological developments for the agro-processing sector:

- Real-time detection of microorganisms in food, using a variety of methods
- Sensors for online, real-time control and monitoring of food processing
- DNA/ RNA chip technologies to speed detection and analysis of toxins in foods
- Food pathogen sensors as small as dust
- Separation modules that force molecules into confined environments
- Prevention of food-borne infection by interruption of pheremonal communication among microorganisms
- Understanding of the physiological and molecular mechanisms of microbial stress responses and associated enhanced virulence
- Understanding of pathogen emergence and interactions with food production processes

- Real-time detection systems for verification and validation of intervention technologies used in Hazard Analysis and Critical Control Points (HACCP) systems
- Better understanding of tolerable intake levels for nutraceuticals/ dietary supplement components
- Techniques to inactivate microorganisms to yield safer foods with extended shelf lives
- Standardized edible food packaging films
- Biological (e.g., bacteriocins) and chemical inhibitors to prevent or slow growth of pathogens in food

The challenge for the future is to maintain the food sector competitive and innovative at a global level, while increasing the safety of production processes along the food chain.

Agro-processing is defined as the processing or beneficiation of primary agricultural products to produce end user products for human or animal consumption. The Agro-processing sector is defined by three core components, namely;

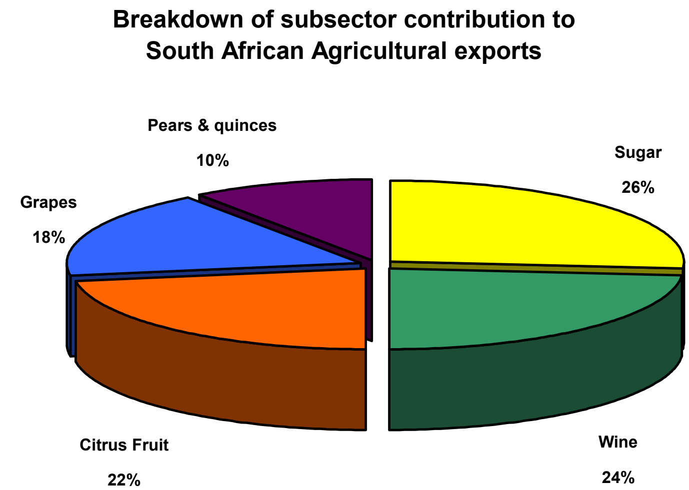
- **Inputs**, including land, plant and machinery; and raw materials such as seed and irrigation
- **Primary Production**, crops and husbandry;
- **Processing**, including the manufacture of composite products (combination of two agricultural products such as pasta or couscous); the manufacture of secondary products (for example, bread from wheat); food processing for consumption (for example maize meal from maize); storage primary agricultural produce; and packaging of both primary agricultural produce as well as processed products.

This study concerns itself largely with the latter component, the manufacturing of food, beverages and tobacco products.

In South Africa the sector has an annual turnover of R 77 Billion and contributes R 124 Billion to GDP.

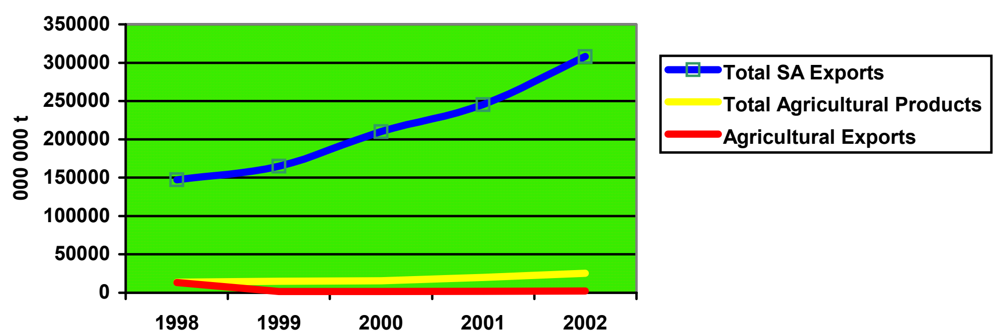
The export of agricultural products including primary produce and processed products is valued at R 6.5 Billion, reflecting a positive trade balance. The following graphs represent these contributions visually:

Figure 24: Breakdown of sub-sector contribution to South African Agricultural Exports



Wine, citrus fruit and sugar exports account for one quarter each of all agricultural exports while fruit account for the balance. It is notable that grapes and wine together account for just over 40 % of exports, reflecting a concentration of a single crop and its upstream product in the export market. Furthermore, the only beneficiated product that has a significant contribution to the export market is wine, suggesting a weak contribution of the processing component within the agro-processing sector in South Africa to South African agricultural exports.

Figure 25: Agricultural export trends 1998 - 2002



The bar graph above represents the trends in South African Agricultural exports. Although South Africa has experience growth in South African export products, we can see a steady decline in agricultural exports, despite growth in agricultural production. This downward trend is further emphasised by manufacturing output growth more generally, specifically tenfold in Automotive Sector since 1996 (BER, cited in SA Yearbook 2003).

This suggests that despite numerous cases of growth in exports and general economic buoyancy, in the midst of turbulent economic conditions globally, the agricultural sector exports are in steady decline.

The industry turnover is highly concentrated in the sectors top 10 companies (of 4000) responsible for 70% of the turnover. In South Africa the sector employs 451 000 people in the formal sector, 5% of the economically active population and 15% of South Africa's manufacturing sector. Notably the beverages sub-sector is well established and growing with SAB as the 2^{nd} largest brewer globally and the largest on the African continent.

12.2 Current Situation

12.2.1 South Africa's Strengths in the Agro-Processing Sector

With co-seasonality with the Northern Hemisphere markets, as well as having the most proximity in the Southern Hemisphere to EU/Far East markets, South Africa has a unique locational advantage in the Agro-processing sector globally. As agricultural markets are increasingly deregulated through trade liberalisation processes, thereby creating broader access to previously inaccessible markets, this locational advantage is presented as an enormous opportunity for South Africa. Furthermore the recent decline of consumer acquiescence to seasonality constraints in the Northern hemisphere further strengthens South Africa's opportunities in the sector.

A largely untapped opportunity is South Africa's advantageous location and capacity in relation with South/South trade (DACST, 2001). The geographical advantage as well as well-developed infrastructure, specifically transport and communication, exposes South Africa to the mass-market developing countries such as South-East Asia, China, India and the east coast of South America with significant competitive advantage.

South Africa's substantial Research & Development institutional base derived from strong tertiary institutions and well organised research funding structures provides an opportunity for the country to invest in intellectual capital. Given that there is global trend towards intellectual versus resource capital in the manufacturing sector more broadly, this presents a powerful driver for technology development in the agro processing sector (DACST, 2001).

The industry locally is well organised with strong governance structures projecting a low-risk profile to international importers. This low risk profile is further buoyed by relatively cheap labour making the cost/benefit of exported South African products attractive and reliable.

South Africa is rich in biodiversity, presenting a unique opportunity that traverses a number of industrial sectors, particularly biotechnology (Blue Peter Management Consultants, 2003). Extensive biodiversity produces a large gene pool of microcosmic organisms that through advanced scientific and industrial research may beneficiate primary products to meet the sophisticated demands of the international market.

12.2.2 South Africa's Weaknesses in the Agro-Processing Sector

Generally, South Africa has battled to make the transition from primary to secondary production and manufacturing. As indicated previously, the strongest beneficiated product in the industry – Wine – only accounts for 26 % of all exports. Our continued reliance on exporting primary products will place us in a weaker position as the world moves from the Industrial to the information Age (DACST, 2001).

With increasing levels of global warming, climates all over the world are experiencing adverse conditions and South Africa is no exception. This has a direct impact on yields, price, and product quality Compounded with poor soil and water resources, the benefits previously enjoyed through the varied stable climactic conditions in South Africa, are beginning to decline.

Combine the general instability of climate with instability in the rainfall patterns in Southern Africa; a major threat to the industry is erratic and unpredictable rainfall patterns.

Although South Africa's foreign trade policy is beginning to show signs of improvement in our trade balance generally, our leverage in the international agro-processing market is still limited This is attributed to our "new entrant" status in a well established global market, with historically entrenched interests, themselves protected by trade barriers, particularly in Europe and the US. With other new entrants entering the market with significantly more competitive packages, such as China, it becomes evident that our potential strengths are severely jeopardised in the global arena. (SA Yearbook 2003)

A significant concern that is both related to South Africa's poor image and weak leverage, is the issue of weak value-adding technologies. As a result of Apartheid-era isolation, South Africa has tended towards producing a range of generic, entry-level products to ensure that baseline nutritional requirements of the domestic market is met. The country's inability to specialise, now that South African export opportunities have expanded with democratisation, reflects an inability to harness the latent opportunities where there is competitive and comparative advantage (DACTS, 2001). Furthermore, South Africa tends towards exporting primary products with no or limited beneficiation., although our processing technologies are relatively on par with comparable exporters. This is confirmed by the Foresight Report (2001) that indicates our inability to invest in technology where there are intrinsic strengths in the sector, is notably weak reflecting a lack of coherent strategy and focus in industrial strategy.

Following from this train of thought, South African producers are not appropriately placed within the supply chain creating a situation of misalignment in terms of R & D, industrial development and capital investment.

Despite the imperative to consider external market forces to a greater degree, the limitations of the South African market also plays a role in limiting technology development. The South African market for value-added products is relatively small and unsophisticated (DACST, 2001). This means that internal demand is not aligned with external demand, particularly the advancing tastes and sophistication of European and American markets. A misalignment in demand develops, adding pressure to producers to meet the entry-level needs of the domestic market as well as the sophisticated needs of the international market. Combined with a general lack of entrepreneurship culture in South Africa, this suggest that South African producers will respond to a greater degree to market demands they consider "low-risk" or more reliable.

An emerging threat to the South African agro-processing sector is the limited compliance with ISO standards. Only 28 food and 10 beverage companies comply with the ISO 9001/2 standards. As these standards increasingly determine access to markets, the "passport" to trade in South African goods will be increasingly limited, unless dramatic interventions are made to elevate South African companies to a an adequate level of compliance.

12.2.3 Sector Specific S & T Focus and Activities in South Africa

The **Micro-economic Reform Strategy** seeks to address internal process and technological weaknesses in industrial sectors. In Agriculture there are a number of efforts relating to government support initiatives, most notable the efforts to support emerging black farmers with technologies to optimise process and add value through indigenous knowledge regimes (AMTS, 2001) .

The **Advanced Manufacturing Technology Strategy** identifies research & development and innovation as key outcomes of the project. The Strategy has also identified agro-processing as a key focus sector for beneficiation initiatives and export-led growth. Implicit in this is a concentration of science and technology interventions including biotechnology, and Information & Communication technology as well as Process Optimisation technology.

The **National Advisory Council on Innovation (NACI)** undertakes research, monitors S & T development, and makes policy and programme proposals to the Minister of Arts, Culture, Science & Technology.

Mathematics and science education. These agreements combine 60 projects with France, China, Ukraine, Belarus, Algeria, Morocco, Tunisia and Pakistan. The **Science and Technology Agreements Committee** (STAC) service the funding and oversight of these projects together with the NRF

The **Lead Programmes Fund** facilitates international cooperation agreements in Biotechnology, Information and Communications, environmental management, rural development and urban renewal.

The **South African Development Community Fund** focuses on collaboration with countries in the region in areas of water management cross border pollution, food technology, indigenous knowledge systems, ICT, soil management and HIV/AIDS.

The **National Biotechnology Strategy** considers new developments in Biotechnology globally and has recently begun implementing Regional Biotechnology Innovation Centres. Three centres have been established to date focusing on human health, industrial biotechnology, food security and agricultural production as well as ICT for the tertiary manufacturing sector.

In partnership with the EU, the DACST has recently launched the Godisa Programme aimed at develop technological capacity in SME's to sharpen their competitiveness in the global environment. A range of incubators have been established, most notable for the Agro processing sector Kwazulu Natal Innovation Support Centre; the Egoli Biotechnology Incubator; and Mbombela Horticultural Incubator. It is expected that the GODISA Programme is to develop into a **National Incubator Programme** and a **National Centre of Excellence**.

The **Poverty Reduction Programme** managed by DACST focuses strictly on the agro processing sector to stimulate job creation through low-tech labour intensive applications. Projects include value-added industries from honeybee production; Oyster mushroom farming; Papermaking and other wood pulp products from sugar cane.

The **South African Environmental Observatory Network**, run by the National Research Foundation has been established to monitor medium to long-term climactic and environmental changes

Technology for Human Resources for Industry Programme (THRIP) is tripartite partnership between research institutions, government and industry to build capacity in industry-led technology applications in agriculture and forestry, bioprocessing, food processing, healthcare, chemicals and minerals, mining, manufacturing and energy.

The National Research foundation's **Research and Innovation Support Agency** focuses on research and development of key competitiveness areas around the following themes:

- Intellectual capital and indigenous knowledge systems
- Economic growth and competitiveness
- Sustainable livelihoods
  - Ecosystems and biodiversity
  - Information Society and ICT's
- Globalisation

The **International Science Liaison** manages relations between scientists, academic institutions and research bodies locally and globally to foster greater knowledge sharing in the science and Technology field, particularly in Africa

The **Foundation for Education, Science and Technology** focuses on building intellectual capital for science and technology amongst learners, particularly in the area of biotechnology.

The **Agricultural Research Counci**l (ARC) promotes agricultural development through research, technology deve3lopment and transfer. The Council undertakes research and policy-making activities in applied Science & Technology, health and nutrition, food safety, and natural resource management. An important achievement of the Council is the establishment of the Agricultural Georeferenced Information System (AGIS) launched during the World Summit on Sustainable Development. This is now available to provincial level detail through an Internet portal. The ARC host a number of institutes related to agro processing.

The **Council for Scientific and Industrial Research** (CSIR) is the single largest industry-directed research agency in Southern Africa. Its activities are vast and focus on market-oriented business units including Food Technology, Water, Environmental and Forestry Technology, and Biotechnology. It also considers manufacturing technologies more broadly such as cleaner production and process optimisation.

The **Human Sciences Research Council** is a statutory body and extends in five centres across Africa. Sector-specific activities include the Assessment Technology and Education Evaluation Programme focuses on identify gaps in the education sector for industry-led science and technology development. The Integrated Rural and Regional Development Programme considers market dynamics in rural areas and in the SADC region, particularly in the agricultural and food processing sectors. The Surveys, Analysis, Mapping and Modelling Programme (SAMM) focus on the knowledge industry and information systems.

The **Council for Geoscience** documents, monitors and analyses geographical information that provides government and industry with relevant investment and risk analyses.

The **South African Bureau of Standards** validates and monitors existing standards and assists measuring new standards and products in industry. It is solely responsible for administering standards regulation on behalf of the state particularly the SABS ISO 9000 Quality Management Certification Scheme and the SABS ISO 14001 Environmental Management Certification Scheme.

12.3 Global Drivers of Change

The production, processing and retailing of food has changed throughout the ast century from local structures into a global production and logistic system.

This development, together with technological progress, led to increased complexity in the food sector. New business opportunities arose for food producers, while at the same time the safety of food production had to comply with higher standards.

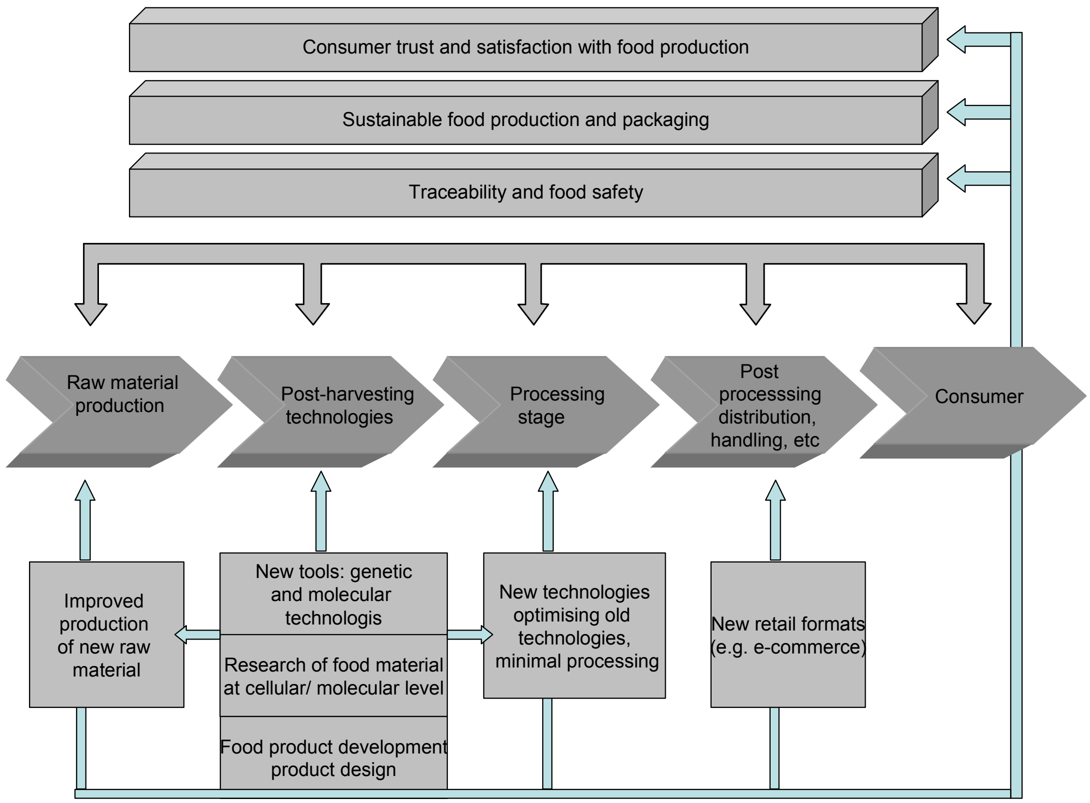
The challenge for the future is to maintain the food sector competitive and innovative at a global level, while increasing the safety of production processes along the food chain.

Recent developments in the food sector (like the development of functional food, the use of GMOs in the food production or the BSE crisis) impressively showed the importance of the consumer sensitivity.

Taking a closer look at the interaction between the food chain and the consumer, the connection between the need for research and consumer benefits can be described along two different lines of issues (as shown in figure 3):

- *Horizontal issues*, which have an impact back from the consumer on the e*ntire* food chain, affecting each single stage:
  - Consumer trust and consumer satisfaction
  - Food safety and traceability
  - Sustainable food production systems
- *Specific issues*, which have special relevance for *individual parts* of the ood chain:
  - Improved production of (new) raw material
  - Research of food material at the cellular/molecular level
  - New tools: Genetics and molecular technologies
  - Food product development/Product design
  - New technologies, optimising old technologies, minimal processing
  - New retail formats

Figure 26: Consumer interaction with food chain



The first horizontal issue, consumer trust and consumer satisfaction, is determining all other issues and therefore requires a proper approach to understand the consumers perception of food and food processing. This demands the development of assessment tools in order to find out what enefits and risks the consumer assigns to the single steps of the food chain.

The consumer acceptance is indispensable for the introduction of new echnologies into the food chain. The example of biotechnology in food roduction indicates that consumers will increasingly call for more information or even active involvement in decisions concerning new technologies in the food industry. This fact gains further importance, as the technology basis of food production will be of increasing relevance for generating and seizing new business opportunities. In this context, research at the cellular and molecular level of food components will play a central role. Although the high relevance of the consumers' point of view was perceived in relation with a series of food crises, this fundamental link should be taken into account by decision-makers in policy and industry also in non-crisis situations.

As food is one of the basic goods, this means that once a basic level of food supply is guaranteed or even exceeded, the consumer develops an increased interest in quality and variety. Through the ability to choose between a broad range of food products, the consumer acceptance of new food is the final criterion for a successful market introduction. Accordingly it will be necessary in the future to take the consumers point of view at every stage of food product development, processing and marketing into account.

Food Safety

Safety in the food chain should be looked at in terms of microbial and chemical issues. This approach assumes, that the main challenge to food safety arises on the one hand from undesired chemical components in foodstuff, or through uncontrolled microbiological activity, (entering through raw material at the starting point of the food chain or via contamination during the processing). One obvious method to cope with this challenge is the detection at the earliest possible stage of the food chain.

Therefore diagnostic tools have to be developed for the entire food chain, which guarantee a maximum degree of prevention of food safety problems of preservation of food quality. The focus for the development of diagnostic tools should again be the starting point of the food chain, close to the raw material production, in order to refrain from avoidable follow up interventions or even the recall of food products from purchase end-points/consumers. The use of molecular monitoring techniques and the increased substitution of animal trials for tissue models are two examples of how diagnostic tools are being improved. “Diagnostic” not only means analytical methods, it also means to establish epidemiological priorities. Analysis usually concentrates on one target substance, be it chemical or microbial. Already existing models can be used for the development of instruments tailored for the food chain, and here the HACCP-systems (Hazard Analysis Critical Control Point) should be developed further.

Health

Contrary to the risk prevention/quality maintenance focus of the discussion of the safety issue, this health issue regards the potential benefits of food products. A division is made between, on the one hand, nutritional improvements are looked at, and on the other hand the role of active molecules, as it is understood in the context of functional food. At the same time it is necessary to analyse the interaction between microorganisms in foodstuff and the human metabolism. This can comprise positive, health improving or negative, health damaging effects. Diagnostic tools have to be developed, similarly to the safety issue. Those would lead to prevention strategies, for which again techniques and models are necessary in order to identify health problems and to develop recommendations. Solution approaches might tackle obesity and other pathologies and may include genetic tools, diet behaviour, etc.

A way forward to increase the nutritional value of food could be based on molecular nutrition. In this context the carbon associated to certain carbohydrates should be examined in order trace its efficient use in energy consumption. Those methods already exist and are used, for instance in tissue models. One could also think of producing food with a therapeutic effect, such as food against diabetes. This is an opportunity, but it has to be discussed if this is not an issue outside the food technology/food safety area and should therefore be left to medical authorities.

Safer Production Methods

Development of safer production methods for animal feed it is important to guarantee high quality input and safety controls at the entrance point of the food chain, the raw material production. Scientific efforts are involved in the steady improvement of animal feed in order to enhance animal health and optimise the conversion of feed into milk or meat. These efforts involve the application of quality assurance programmes, using traceability systems along the manufacturing process, and the participation in communication of food safety related aspects. In this respect, the use of animal models will be essential because actual pathogenicity can not be studied outside the intestinal ecosystem yet.

Beyond the traditional food preservation methods of thermal processing, freezing, salting and drying, new methods of processing and packaging are emerging (ultra-high pressure hydrostatic processing or pascalisation, ohmic processing, high-intensity light pulses, high electric field pulses, radiofrequency (RF) heating, osmotic dehydration, irradiation, microwave processing, thermo-sonication, modified atmosphere packaging (MAP) and active packaging. These can extend the shelf life and freshness of perishable foods.

Understanding interactions of food (ingredients) and processing at the molecular and cellular level. This deeper knowledge has to include technologies from other disciplines. Additionally, raw material can be modified in order to improve its properties/performance throughout the single process steps. Consequently, one of the most intensely discussed issues was the need for increased research at the cellular/molecular level. According to the experts, new techniques such as genetics and molecular technologies make it possible to analyse the relation between structure and functionality of food material and develop on this way a new and deeper understanding. This could be for instance research on the synthesis and degradation of cell walls, in order to increase the stress resistance of raw material throughout the postharvesting/ processing/post-processing steps of the food chain, and therefore to maintain a high quality of the food.

Impact of Food on Health

Gentle processing

Gentle processing - generating and maintaining health-promoting quality also impacts on applied technologies in food processing. Different developments are under discussion. Food production systems have to be able to deliver fresh food to the consumer, retaining the quality of the raw material throughout the entire process to the highest possible extent. One possibility therefore is to minimise processing of food material. In particular these efforts are devoted to reduce the intensity of the technological damage mechanisms. The result of this effort should be a gently processed food that maintains the quality level that is characterising the raw material. It may be likely that the use of emerging non-thermal technologies may allow the utilisation of novel raw materials, resulting in unique functional foods. Food technologists have to demonstrate that new food products are safe and equivalent to those made by "traditional processes". This will lead to decisions regarding the selection and use of appropriate technologies. The trend of minimal or gentle processing needs the support from a continued basic research in different areas. As heating can destroy sensitive food ingredients, e.g. vitamins, modern pulse heat treatment involves very brief heating interspersed with cooling phases. Air filtration, aseptic packaging and protective atmospheres are used to reduce food spoilage, but freezing still 49 plays a key role. Therefore, current research efforts on changes of nutrients and texture in foods during cold storage to further optimise freezing processes and product composition are of great importance. Also packaging offers diverse opportunities such as "Active packaging" to enhance freshness characteristics of raw or pre-treated food products, development of visual indicators for thermal stresses for refrigerated/deep frozen products or in the development of new packaging formats adapted to specific consumer segments. A synergetic effect in maintaining food quality and increasing sustainability is obtained by means of packaging technologies (new environmental friendly packaging methods and materials like edible coating/biodegradable films with enhanced barrier characteristics etc.).

Improvement of health generating properties of new food raw materials

Biotechnology research, through developing new varieties, holds the potential to enhance the nutritional content of agricultural products and lead to improvements in agricultural techniques, resulting in both increased productivity and reduced environmental impacts along the food chain.

Process design, product design, and information technology

Information technologies have been introduced first in the processing stages of the food chain, for the diffusion of information and control of different processing steps, and later in the raw material production at one end and in the post-processing steps at the other end of the food chain. Development and implementation of bioinformatics may represent, in fact, a powerful tool in the development of genomics, involving a series of potential applications.

Traditional ways of product development by trial and error are too time consuming to meet the demands of the market. Therefore, industry has an increasing need for predictive knowledge. New techniques combined with computer technology can become a predictive power if physical, chemical and biological characteristics of the raw material (such as denaturing temperature, pH dependence, salt and protein concentration, aroma production, etc.) are known, in order to predict the process and product properties (novel cheese production, etc.) The traditional control of the end product is no longer satisfactory. Systems with on-line sensors, in combination with computer simulation programs, will gradually replace quality control systems at the end of the production chain.

Environmentally, friendly processes will rise on the priority list of production management, such as savings in energy, water, raw material and waste discharge. Computer models are under development that give insight into process data as well as connect these with product properties. The utilization of information technologies along the whole food chain in an integrated system may be moreover devoted to offer an actual traceability system in order to go back from the plate to the farm that is necessary both for safety reasons and for certification of typical products with certified origin. Vertical integration in the food chain (e.g.: poultry meat and dairy sector, infant foods, food products labelled by major distribution food chain) makes it possible to exploit the benefits of information technologies in the most efficient way.

Analysis/Detection of Contaminants and Pathogens

Sensor development (rapid, non-invasive) is essential for detection and analysis/identification of allergens, food contaminants, pathogens, prions, foreign matter, hormones New molecular technologies might not only be used to enhance properties of raw material and food products, but also for the development of sensors for chemical and microbial contaminants and pathogens. Both for organic and for conventional food products, possible hormones residues, phytohormones and other metabolically active components in food need to be monitored.

Another major safety aspect consists in mycotoxines concentration in diet constituents. These sensors could be applied in the frame of HACCP systems along the food chain for routine controls, but also to react to emerging food crises, in order to be able to provide quick information on the location and spread of contaminations, and to develop counter strategies.

Detection of non-intentional horizontal genetic material transfer

This research priority refers to horizontal gene transfer related with GMP's (Genetically Modified Plants) field release, with specific reference to gene transfer to related plants, starting from the risk associated with gene flow via outcrossing to sexually compatible plants in ecosystems, or even gene transfer to unrelated organisms. This has to be investigated in detail for newly introduced GMP to make a correct environmental risk assessment possible. This is particularly important when considering the centres of origin and genetic diversity for specific plant species.

Traceability

Due to recent food disasters such as the bird flu virus and salmonella poisoning of poultry originating in the Far East, and BSG in beef from Europe, the global players in the industry, global regulators and importing governments are increasingly concerned with tracing and validating the source and quality of agricultural produce. Biotechnology, gene technology, digital technology and information technology are playing a significantly greater role in establishing food safety.

Research in this area has to be developed further, taking into account on the one hand new insights and discoveries made in the last years, and applying new technologies on the other hand. This should lead to a whole range of new tools, utilising aspects of HACCP systems, Bioinformatics, Proteomics, PCR, DNA micro array techniques, Functional Genomics, Fingerprinting, ELISA methodology (enzyme-linked immunosorbent-assay) etc.

These tools will need the support of appropriate information technologies in order not only to obtain the appropriate information in an efficient manner, but also to create systems which are able to provide the information to food producers and consumers in the appropriate form. One specific issue which might receive special attention within the research issue traceability is the development of information carriers/markers. The technology is available with e.g. radioactive tracers, or resistance markers in the case of trasgenic plants and animals.

Especially the latter case is controversial concerning it's long-term effect on human health (related to antibiotics which have been used for transgenics), which makes it even more necessary to develop new information carriers. Also here the use of information technology is needed.

Environmental Health Risks

Understanding the development of allergens - activation/generation

Food allergens are increasingly becoming a major clinical problem. Both the incidence and severity of allergic diseases are increasing and the age of troubled patients is declining in industrial countries. Approximately 75% of asthma cases are triggered by allergies and the mortality due to asthma has increased considerably over the past 20 years. An increasing number of biotechnology based approaches could be used to solve different food safety issues, including them food allergy. Probiotic administration to infants can decrease allergic symptoms and thus can effectively break the typical progression of allergic symptoms. Thus, further development of rapid tests for allergens and improved process control to minimise contamination of allergens is needed. New (molecular) technologies should be applied to understand the mechanisms of allergens. Important questions here are the generation of allergens, and how they are activated/deactivated. New insight concerning this relation should be applied directly to the development/design and the improvement of properties of raw materials and food products, in order to avoid new allergenic proteins. It is also important to understand the threshold of allergenic reaction in sensitive groups. This is important, as there are no zero levels for allergens in food and the knowledge of thresholds allows then to produce allergen-free products even for sensitive groups.

Work and lifestyle

There are a number of general trends that drive technology development more broadly that must be noted in this discussion. The organisation of the workplace and its impact on lifestyle is a critical consideration. The Department of Science & Technology's Foresight Report (2001) identified the following general trends that will affect manufacturing in medium to long term (10 – 50 years):

- Service industries will dominate manufacturing
- Intellectual capital will dominate over resources (capital, land and labour)
- The information age and its components will penetrate all the facets of industrialism
- Organised labour will extend its prevalence making stakeholder management a key factor of production
- The flexibility and dynamism of small enterprises will replace the mega-organisation in the value-chain

Supply Chain Management

The concept of value chain management seeks to optimise the value created at every stage of production through limiting value chain activities that do not make a significant contribution to profit or optimisation or vice-versa; identifying and eliminating wastage , leakages and seepage; lowering costs and price; increasing quality and output; and, enhancing service standards. It is anticipated that these drivers will increase reliance on information and communication technology, as well as people and leadership development in the workplace (Department of Arts, Culture, Science & Technology, 2001).

Product & Process Development

Three key considerations are pertinent to this discussion in the product and process development sphere. As mentioned above, the flexible organisation and flexible production will prevail; Computer assisted processes and products will dominate; and resource management for environmental sustainability will be a critical competition factor.

Nutritional Health

The nutritional requirements of the Development Aid industry and the search for cost effective nutrition products for people affected by HIV/AIDS (especially in the developing world), has presented an increasing demand for processed foods that travel long distances, are easily packaged and stored and have a high nutritional value. When this scenario is pitched against decreasing landmass for agricultural yield, and adverse environmental conditions, the trends towards biotechnologically beneficiated-processed foods is gaining momentum.

Given the dramatic scientific findings on the dynamics of nutritional health over the past twenty years, there have been major shifts in the demand for agricultural products. More specifically the demand for products with proven nutritional benefits and improved food quality with limited synthetic additives is increasing.

High Performance Packaging

Related to the previous two points, therefore, the need for high performance packaging is emphasised particularly for perishable products that travel long distances and where nutritional integrity must be maintained. Furthermore, environmentally sensitive consumers, particularly in the Northern Hemisphere, have increased the demand for packaging that meets the requirements of biodegradability and recycling standards.

Co-seasonality

With the expansion of markets and increased access to previously inaccessible markets, as well as a general increase in multi-cultural awareness across the globe, a seasonality-oriented consumption culture is declining. As a result the need for atmospheric-related production and packaging is of a higher priority.

12.4 Technology Development Trends

Six broad technology development areas will be important in the future:

- Designing foods and diets for weight loss
- Improved methods for identifying and evaluating components of functional foods that reduce chronic disease risk
- Improving nutrient levels through genetic modification of crops
- Evaluating the effects of processing, storage, and genetic modification on the nutritional value of foods
- Food components that improve blood lipid profiles and glyceamic responses

Food scientists will increasingly borrow and apply advances from other areas including robotics, genetic engineering, and nanotechnology.

The next few decades will see more research into pro-biotic and pre-biotic products, functional foods, nutritionally appropriate convenience foods, and environmentally friendly agricultural products.

Research into the production, consumption, safety, and benefits of nutraceuticals will increase.

Nanobiotechnology

Nanobiotechnology, the study of biology at the nano-scale, will have an impact on food science in the future. Advances in the field will enable:

- Smaller, more robust sensors and devices, e.g., handheld pathogen detectors for food safety workers
- the isolation and study of single molecules, e.g., to study the qualities of chemicals used in flavoring foods and beverages more rapid and specific separation technologies based on the behavior at the molecular level.

Food safety

Food science may reach a point at which most bacteriological, viral, and protozoan food pathogens have been identified and their behaviors known.

There will be increased research into food safety and on emerging thermal and non-thermal technologies for destruction of pathogens.

Fluorescent and luminescent labeling, which helps scientists track bacteria in plants, food, and animals, will lead to better intervention strategies against food-borne pathogens.

By using technologies like DNA and protein arrays, researchers will gain a better understanding of how food-borne pathogens operate at the molecular level.

Genomics and proteomics will help food safety researchers understand microbial virulence and create better testing methodologies. Researchers will study microbial ecology in order to identify critical control points, develop intervention strategies, and construct accurate risk-assessment models.

Food engineers will explore use of microelectromechanical systems (MEMS) and nanotechnology in the design of biosensors for detecting pathogens, spores, meat tenderness, food spoilage.

Food processing

Research into traditional processes (e.g., baking, pasteurizing, canning) will continue, but the emphasis of food engineering research will shift to non-traditional processing.

Future technology development will be in areas such as microwave and radio frequency (RF) processing, ohmic and inductive heating, highpressure processing, pulsed electric fields, ultraviolet (UV) light, ultrasound, and pulsed X-rays.

The shift to non-traditional processes will be driven by concerns about high levels of the possible carcinogen acrylamide found in fried and baked foods.

Research into solutions that combine non-thermal food processing technologies, natural preservatives (e.g., bacteriocins), and enhanced packaging technologies will continue for the next several decades.

Food engineers will develop better extraction, separation, and purification processes for phytochemicals and biologically engineered plants and animals.

Predictive models will be increasingly employed in food processing research, e.g., to estimate the effectiveness of a processing technique like pasteurization.

Food properties

Non-destructive techniques like magnetic resonance imaging will be increasingly used to investigate the rheological (i.e., flow) properties of foods.

Improvements in computational fluid dynamics will result in mathematical modeling of complex phenomena in foods (e.g. modeling of heat transfer from fluid and solid food interfaces).

A better understanding of the functions of food molecules will allow for new options in food texture and packaging.

Nutrient function

Knowledge of nutrient function will improve, aided by advances in genomics and proteomics.

Bioinformatics will be key to a deeper understanding of nutrition, helping food engineers select the best ingredients for food.

Researchers will learn more about the interactions among food ingredients, e.g., how two ingredients may combine to produce a health function not experienced when the ingredients occur alone.

There will be a better understanding of the effectiveness and pharmacokinetic properties (i.e., absorption, metabolism) of functional foods and nutraceuticals.

A key technological requirement is the reliable methods for screening and accessing ingredient functionality

Dairy foods

Research into new dairy foods and processes will be driven by consumer demands for better taste, nutrition and health, product safety, convenience, and value.

Gene-based approaches will be used to identify the specific bioactive molecules that give dairy products health benefits.

Improved membrane technologies and ion exchange processes will allow researchers to concentrate and isolate beneficial bioactive molecules.

Low-temperature processing techniques, such as high pressure and pulsed electric fields, will be improved. They will help to retain freshness, flavor, and biological activity of dairy products.

Technology requirements

- A better understanding of the component interactions and flavour properties of dairy products to produce foods with new flavours and textures

- A new analytic techniques to determine bioactive components in dairy foods and monitor for changes during processing, storage, and distribution

- Techniques to trace dairy products to the source cow to meet consumer requirements for safety

Food microbiology

Nonculturable flora in foods and the human gastrointestinal tract will be discovered and monitored via DNA cloning, amplification, and sequencing technologies.

Sequencing of the genes of pathogens and spoilage microorganisms will ensure a safer food supply. A marriage of the food and pharmaceutical industries is imminent.

Current high-priority food safety issues include:

- Multi-antibiotic resistant strains of salmonella and other foodborne pathogens safety of genetically modified foods (e.g., in terms of allergens)

- Reusability of water in food processing facilities is becoming a necessity. To fight food- and waterborne diseases, more needs to be known about microorganisms and their interactions with each other and the environment.

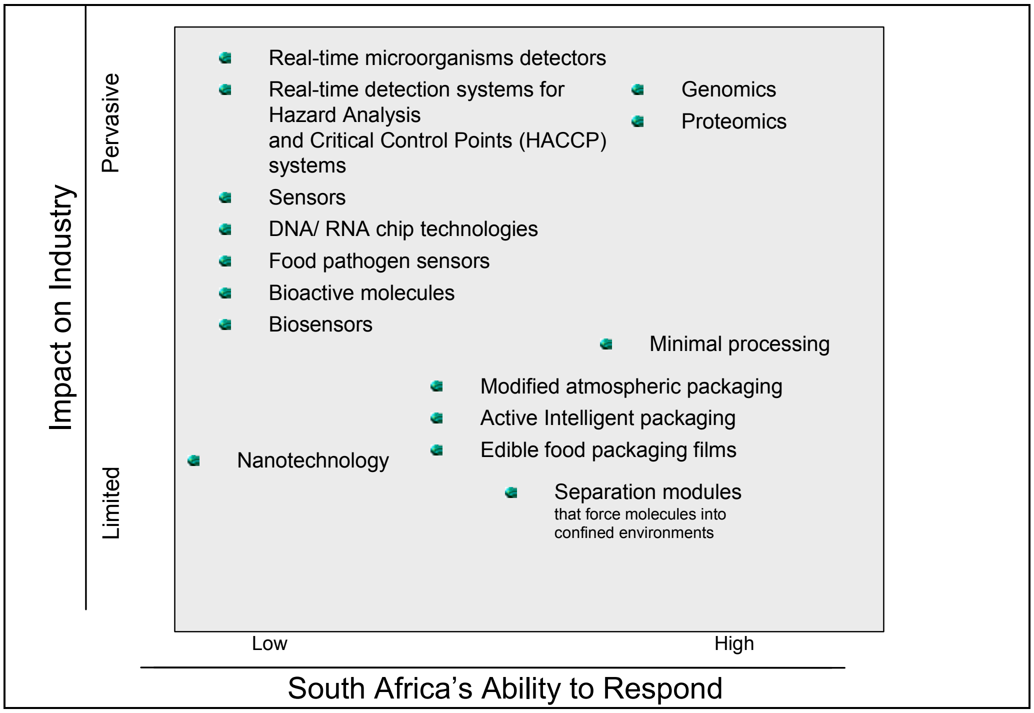
Technologies to remove naturally occurring toxins and contaminants and to prevent the formation of toxic compounds during processing and storage are essential for food safety. Opportunities exist in the food micriobiology area for real-time analyses of foods' constituents, to combat terrorism.

12.5 Conclusions

The following list summarizes the important technological developments for the agro-processing sector:

- Real-time detection of microorganisms in food, using a variety of methods
- Sensors for online, real-time control and monitoring of food processing
- DNA/ RNA chip technologies to speed detection and analysisof toxins in foods
- Food pathogen sensors as small as dust
- Separation modules that force molecules into confined environments
- Prevention of food-borne infection by interruption of pheremonal communication among microorganisms
- Understanding of the physiological and molecular mechanisms of microbial stress responses and associated enhanced virulence
- Understanding of pathogen emergence and interactions with food production processes
- Real-time detection systems for verification and validation of intervention technologies used in Hazard Analysis and Critical Control Points (HACCP) systems
- Better understanding of tolerable intake levels for nutraceuticals/ dietary supplement components
- Techniques to inactivate microorganisms to yield safer foods with extended shelf lives
- Standardized edible food packaging films
- Biological (e.g., bacteriocins) and chemical inhibitors to prevent or slow growth of pathogens in food
- Knowledge of the genetic composition of key microorganisms known to be important in foods

Figure 27: South Africa's Position with regards to Important Technologies



These technological developments represent a variety of opportunities for providers of products and services across sectors.

There are opportunities for companies to help governments assure the safety and integrity of crops, food ingredients, and finished food products. Areas of opportunity include high priority risk areas, bio- and chemical sensors, and surveillance and testing.

Security needs may require enhanced monitoring and tracking of ingredients and products from farm to retail.

The report indicates that the interests of food and pharmaceutical industries are converging. This could provide opportunities for collaboration, and perhaps even mergers across these industries, but will also give traditional food companies a new competitor to guard against.

At the same time, food companies that associate themselves with the perceived complexity and health risks of pharmaceuticals may find themselves facing rising doubts about the "simplicity and purity" of their products.

An increasing focus on genomics as a means to improve nutritional value and safety of food implies that there will be an increased need for food safety and nutrition researchers who are cross-trained in genetics.

Several mentions of nanotechnology in the articles indicate that this emerging field is piquing the interest of food technologists. A more in-depth scan of nanotechnology will be needed to assess useful applications in the food industry and the appropriate levels of investment to give it.

12.6 Technology Support for Sector Development

12.6.1 Australia

Australian export products account for 2.7% of world food trade and is growing export industry by an average of 6 % per year. In general growth terms the industry growth overall is 2.7 % just lagging behind general growth of 3.6 % which by contemporary terms is considered to be a healthy growing economy.

Food Processing is Australia's largest Manufacturing sector comprising 22 % of all manufacturing. Food products comprise 20 % of Australian exports. In 2001, the trade surplus in food processing amounted to A$ 26 Billion. Agro processing is a critical industry in supporting rural development in Australian with more than half of all employees in the industry resident in less urban areas.

Compared to European figures of 1%, Australian R & D investment stands at 0.3 %. A number of general industrial development grants are available for sector development and are largely focused on research & Development as well as innovation. These include:

- The **Innovation Investment Fund** leverages venture capital for start-up initiatives
- The **Commercialising Emerging Technologies Programme** provides grants for commercialisation of innovative products and service.
- **Ausindustry** implements a variety of programmes that support research and innovation
- **Austrade** provides export development grants
- The **Rural Industry Research Development Corporation** assists rural industries undertake research and development projects, however this emphasises production versus processing.

Current science and technology focus of agro processing in Australia

Being a significant contributor to GDP as well as an environmentally vulnerable sector, Australia's agro processing sector is highly institutionalised and focuses on a strategy-led model of technological development.

Similar to foresight methods, Australia undertook a technology planning process, which culminated in the National Food Industrial Strategy. This strategy identified roles for different players in the industry particularly, the Regulating body – The National Food Industry Council (NIFC) – and the Department of Agriculture, Fisheries and Forestries (DAFF).

The DAFF is responsible for four key areas, namely:

- **Patent Reform**: Enabling extensive agro processing patenting and supporting patents in the global market

- **Centres of Excellence:** provide scientist and researchers develop innovative processes and products in a “soft” environment

- **Sector Collaboration:** Provides a platform for industry players communicate and collaborate efficiently and effectively

- **ICT Development:** ensures that the agro-processing sector benefits from the latest ICT technologies

The NIFC is responsible for more direct market-oriented interventions, namely:

- **Innovation:** Recognising that industry growth is largely attributed to diversification rather than value-add of primary products and beneficiation, the NIFC makes available grants to support technology development and Australian innovation in the Agro processing industry. Specifically the Food Innovation Grants provide the following on a dollar-for dollar basis:
  - Establishment funding for new products, incl. Plant and Material, research & Development, as well as patenting;
  - The grants are conditional upon applicants providing a cost/benefit analysis that stream project activities to from initiation to commercialisation.

The innovation thrust also concentrates on spreading the risk across the industry and the value-chain to mitigate environmental impact on primary producers.

Market Development: The NIFC undertakes specific market intervention activities to promote market penetration globally, expansion of existing opportunities and consolidation and securing of niche markets. It does this through market intelligence and research product promotion; industry collaboration and partnerships; and technical skills development.

Business Environment: The NIFC regulates and coordinates business environment conditions to promote enhanced competitiveness and efficiency in the sector. This is achieved by developing a compact between government, industry and consumers; promotion of value-chain integration; development of workforce skills; management development programmes at secondary education levels; and information management systems.

Environmental Sustainability: The NIFC undertakes and supports programmes that ensure Australian products comply with global environmental standards (ISO). This thrust also supports market-based approaches to environmental sustainability such as waste management, recycling and water and soil conservation.

12.6.2 India

India is in the fortunate position in the developing world of reaching sustainable domestic food security. Simply put, this means that it can feed its population adequately with its internal resources. Cereals account for one fifth of the consumption in India followed by rice and grain. Although currently processed products are not popular, the burgeoning middle-class is expected to increasingly access such products on the domestic market. It must be noted that the domestic market for Indian products contributes to its significant global market advantage.

India accounts for 14% of global rice production following China with 28 % of the global market share, which, for a developing country is a substantial market share. Furthermore, 30% of global what production takes place in India, the fourth largest producer after the USA< China and Russia. India accounts for the second largest milk production market share in the world after the USA. India is currently the leader in fruit growing with sizable processing leaders in Brazil, Maylasia, the USA and Israel. India is the second largest producer of vegetables in the world next to China and accounts for 15% of all vegetable growing.

- India identified agro-processing as an important sector because:
- Its significant socio-economic impact on the local population which is itself is a sizeable market
- Its potential growth in exports given India’s natural resources and capacity
- India’s competitive advantage in the global market
- The high beneficiation potential of agro processing more generally
- The industry’s technology impact on related sectors
- The industry’s role in sustainable development.

In order to adequately target Science and technology interventions in Agro-processing, India undertook a process of technology foresight for the Agro-processing Industry. The process culminated over a period of two years in a comprehensive Science and Technology Strategy the process was championed by a leading industrialist under the auspices of the Technology Information and Forecasting Assessment Council (TIFAC). The process included input from industrialists, government officials, academics, small producers, consumers and industry experts.

In short, the agro processing industry is a significant sector for Indian export growth and sustainable development. The sector employs a significant portion of the population therefore having significant multiplier effects on household and community sustainability.

Broadly the process highlighted the following technologies for advancement in terms of immediate, short, medium and long term needs and a sophisticated SWOT Analysis:

Table 32: Summary of Composite priorities for Agro processing Technology Development in India

SUB SECTOR	THREATS/RISKS	OPPORTUNITIES / STRENGTHS	TECHNOLOGY
Dairy	Unproductive cattle	Largest milk producer in the world	Artificial insemination Multiple ovulation Embryo transfer
	Low milk yield		GM cattle feed
			Bypass protein feed
	Metals / pesticide / bacterial content		Enzymatic Protection Lactoperoxidase systems
	Only 12 % of dairy is processed	Primary processing technologies widely available but unused	UHT Treatment Aseptic Packaging
Cereals	Wastage from sub-standard storage	Significant producer globally	Modified/Controlled Atmospheric bulk storage technologies Polly-lined bags
		Increase in food grain consumption	
	Significant losses from inadeq. Transportation		Mechanised, handling, loading and unloading devices
	Outdated sorting technologies		Enzymes Mechanised milling and husking technologies Water-jet Polisher
FRUITS & VEGETABLE S	Poor seed	Largest producer of fruits in the world	GM seed and other GM planting material
	Low yield		Process optimisation technologies Hybridation Tissue Culture
	Inappropriate packaging	Changes in consumer tastes	Irradiation CAIMA Freezing Dehydration

Current science and technology focus of sector within the country

India has a national department of Science and technology that is responsible for oversight of science and technology in the country. The DST has recently developed a Science and Technology that seeks to entrench the notion of technological development as a key driver for economic growth. The Policy also seeks to broaden access to science and technology at school levels, among women, SME's and rural enterprises.

The main institutional driver of technology development India is the Centre for Scientific & Industrial Research. The CSIR focuses on a number of sectors but the Agro processing and Natural Products

Division is its largest. The division focuses on Oil Seeds, Spices and Herbs, and Animal Feed. And its activities are primarily based on beneficiating natural products easily available in India. A significant portion of the activities focuses on biotechnology for health applications. To date the CSIR have developed the following industry applications:

- Palm Oil Milling
- Extraction of carotene rich red palmolein
- Refinement of Rice Bran Oil
- Integrated Processing of fresh coconut and spices
- Extraction and separation of phytochemicals from oil seeds
- Chemical, Biochemical, and nutritional database for oil seeds and their products

The state have invested State-of-the-Art infrastructure into the division, including new generation process equipment and sophisticated analytical instrumentation.

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