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FINAL SECTORAL REPORT –BIOTECHNOLOGY SECTOR (ICT DIFFUSION AND APPLICATIONS)

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Submitted by

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Photos courtesy of AfricaBio (*www.africabio.com*) and the Consultative Group on International Agricultural Research (CGIAR) (*http://www.cgiar.org/photo/*)

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Executive Summary

Background and Motivation to Information and Communication Technology (ICT) Diffusion Project

This report represents part of the second Phase of an eight-sector study, commissioned by the Department of Trade and Industry and funded by the European Union, to examine:

i) The likely trajectories for the absorption of ICTs in a range of economic sectors; and

ii) How to adjust the policies and strategies of the government and the domestic private sector to maximise the benefits to South Africa from the insights flowing out of i).

The project builds on existing research work but has at its heart the analysis of a number of 'vertical markets' for ICT, first through a worldwide scan (Phase I) and then through sectoral research in each of the chosen eight sectors.

The sectors selected were drawn from three broad categories – traditional sectors, service sectors, and new economy sectors, as follows:

Traditional:	**New Economy:**	**Service:**
Platinum Mining	Biotechnology	Cultural Tourism
Automotive Manufacturing	Multimedia	Healthcare Information
Clothing Manufacturing		
Deciduous Fruit Farming		

The objectives of the research work were to:

- Generate accurate, objective findings regarding patterns for absorption of ICTs in a range of SA economic sectors, in order to guide South African participants in vertical markets for ICT;
- Provide recommendations for impacting public and private sector policies;
- Guide the government in directing some of its existing and future intervention strategies, including research and development programmes and industrial development facilities, whether through the science vote or departmental programmes; and to
- Give government more guidance regarding the commitment of funds for human resource development.

Project Research Methodology

The overall approach adopted by the lead consultants was to use Sectoral Experts for the interviewing and primary research, with three ICT coordinators (responsible for up to three sectors each) ensuring consistency across the sectors. An International Consultant was employed to provide an external perspective to the research.

The research methodology for Phase I of this project (The International Scan) involved:

- Defining each of the eight industry sectors;
- Identifying the main players in the value chain; and then
- Performing secondary research on each of the sectors to obtain current data about the diffusion of ICTs into those sectors; and
- Identifying leading-edge applications, as far as possible.

Phase II (Diffusion of ICT in South Africa) involved the use of these sector and value chain definitions to identify the major role players and to set up interviews, based on a structured questionnaire, with selected stakeholders across the value chain.

The questionnaire consisted of both a generic section (i.e. used by all sectors) and a sector-specific section (i.e. aimed only at those interviewees within the sector). Most of the questions relied on the *perception* of the interviewee. A rating scale was typically used, but a number of 'open-ended' questions were included to allow interviewees to express opinions in a less structured way.

The questionnaire was subdivided into six generic sections and one sector-specific section:

- Background Information (Name, Address, Organisation Size, etc.)
- ICT Usage (of Technology and Applications)
- ICT Spending Patterns
- Sources of ICT Information and Training
- ICT Adoption: Drivers and Barriers
- Diffusion of ICT into Organisation/Sector
- A sector-specific section dealing with issues of importance to the particular sector.

Between 40 and 55 interviews were conducted per sector; these should not necessarily be construed as being representative of the sector, as the selection of interviewees was often dependent on personal contact from the sector researcher. Also, the responses from those interviewed undoubtedly contained an emotional bias (for example, the desire not to seem technologically backward), which would have influenced the responses. Hopefully, these biases have been minimised through the averaging process.

Analysis of the Results

The results from the questionnaires were captured on an Excel spreadsheet and a basic analysis performed centrally. This information was then fed back to the individual sector researchers for further analysis and comment. The generic portion of the questionnaire captured up to 117 separate items of information per respondent (either a rating, a comment or basic data), so that a typical sector analysis involved 5000+ items. These responses were subdivided into various categories (e.g. Large, Medium, Small organisations) as applicable and further iterations performed.

Most of the results were shown graphically for ease of comprehension, although only basic statistical analysis was performed due to the nature of the data.

Overview of ICTs in the Biotechnology Sector

This report was informed by results obtained from a survey of the various industries and research facilities that make up the Biotechnology Sector, both in South Africa and internationally (Phase I of this project).

There is as yet no defined biotechnology 'sector' in South Africa and the development of the sector is still immature. Most of the activities are focused at the R&D level, and the application of biotechnologies within certain defined sectors. Estimated R&D spend has increased from R 100 million to R 200 million since 1997. There are no estimated figures available for the South African biotechnology market – this is an area where further research is needed. There are no available figures on ICT spend in the 'sector'. Biotechnology is heavily dependent on intensive use of ICTs. As biotechnology evolves, the volume of biological information is growing rapidly. The ability to collect, manage, manipulate and apply this resource depends increasingly on ICT capacity. Large multinational ICT companies such as IBM are increasingly seeing their own future in becoming bio-industries. This trend is not as yet reflected in South Africa and there is little interest from the ICT industry in exploring such potential opportunities. The development of a National Biotechnology Strategy in 2001 will go some way towards supporting increased R&D activity in this area, and future research will hopefully see an increased number of companies building on this intellectual capital.

This project had the objective of eliciting opinion from a broad range of stakeholders, large and small, concerned with different aspects of the Industry. More than 150 questionnaires were sent out by fax or e-mail - 47 organisations (some organisations had more than one person taking part in the interview) were interviewed across the value chain. The following specific sectors were targeted: food and agriculture (including beverage); pharmaceutical and medical (including veterinary); industrial (including chemical, mineral and environmental). The interviewees who participated in this study came from the following categories:

- Companies;
- Suppliers;
- Sectoral Associations;
- Research Organisations;
- Academia;
- Government Departments; and
- Investors and key international linkages.

There was a lack of interest from companies in the industrial as well as the medical and pharmaceutical sectors, in participating in the survey. Many of the people targeted felt the survey form was too long and were not prepared to spend the time to be interviewed. Academic institutions responded well and there was a good sample spread across organisation size - 34% large, 13% medium, 19% small, and 34% micro-sized. Data was analysed in most cases according to organisation size, since this reflected the most revealing trends in ICT uptake and use.

The following results emerged from the survey:

ICT USAGE

i) The biotechnology sector shows a very high usage of personal computers and hardware such as servers (on average one personal computer to two employees based on the survey results). CAD/CAM is primarily used by large organisations. Emerging technologies such as robotics and sensing devices are not well used across the sector, possibly because some of these technologies are not relevant to the industry yet.

ii) Local Area Networks (LANS) show high levels of usage by all categories of organisations, whereas the use of Wide Areas Networks (WANs) is, not surprisingly, more prominent in medium to large organisations.

iii) Dial-up connections are used predominantly by micro-organisations, but also used to a lesser extent by the larger organisations, mainly by staff requiring Internet access from their homes. Generally teleworking was not widely used across the sector, irrespective of size.

iv) All companies indicate very high levels of e-mail, Internet and Intranet / Extranet usage, as well as CD-ROMs. This is indicative of a sector that relies on strong national and international networks, with high levels of interactions and an emphasis on collaborative research ventures. ICT forms the backbone for these virtual networks as demonstrated by the fact that 85% of the organisations interviewed have a Website.

v) It is significant that the use of tele- and video-conferencing was low across all companies, but understandably so in the micro-sized organisations. Comments from survey respondents indicate that this is an area that could be exploited more fully for communications and building relationships with customers.

A number of barriers were identified by respondents, the most prominent being the inadequate provision of bandwidth by Telkom, and the high associated costs. Telecommunications speeds are also too slow for the nature of the work required in the biotechnology sector.

ICT APPLICATIONS

i) All respondents showed high levels of ICT use in most of the business process components. There were significantly higher levels of use in the business support area e.g. finance, accounting, payroll, etc. Of significance are the relatively lower levels of usage in marketing. Several respondents raised this as a concern, although reasons given were that existing and potential customers were not using ICTs extensively and therefore were not 'ICT-ready'.

ii) There was low usage of e-commerce applications, both B2C and B2B. Several respondents noted the need for better Web-based marketing and provision of services to national and international customers.

iii) There was fairly extensive use of online services, and the provision of information showed high levels of ICT usage across the whole sector.

iv) ICTs were extensively used in data collection, management and manipulation, and to a lesser extent in diagnostics, imaging, sequencing, and detection systems. There was relatively lower usage in areas such as molecular modelling and identity preservation systems.[1]

[1] Molecular modelling and identity preservation systems (as used in the identification of GM and non-GM products for example) are a definite need for research purposes in South Africa – if the sample had included more researchers the

An area of concern is the weak and inadequate support provided by ICT service providers. Many do not understand the needs of this ICT-intensive sector and cannot provide the necessary expertise on specialised support systems.

The lack of affordable ICT applications and systems, as well as the high cost of computing power that meets the needs of the sector, were also mentioned.

ICT SPENDING

v) Large organisations perceive their spending on ICT hardware and software to be more than the norm for the global sector, whereas small and micro-sized organisations saw their spend as below the global norm. Within all organisations, the ICT spend is on the norm or above, with indications that ICT budgets are growing. This would be expected, as the biotechnology sector cannot operate without ICT systems and applications.

SOURCES OF ICT INFORMATION AND TRAINING

vi) The common sources of ICT information were experts within an organisation, and the Internet. Trade associations, chambers of commerce and government initiatives were hardly used. This is an area that requires more emphasis as these organisations could play a role in stimulating ICT diffusion and business development.

vii) Sources for training followed the same trends as those for sourcing ICT information. Most respondents source their ICT training from experts within their organisations, in-house training programmes and the Internet. ICT suppliers were also rated high as a source of training.

DRIVERS AND BARRIERS TO ICT ADOPTION

viii) The most important factor influencing the sector is the general economic climate. The strongest driver is expected to increased competition in the short-to-medium term, and new opportunities for business development through ICT.

ix) On the whole, the culture and attitude of the sector towards ICT is regarded as having a positive influence.

x) The strongest positive influences in the adoption of ICT are the need to: improve communication, respond to customer requirements, respond to national or international regulatory or environmental standards, increase organisational efficiency, and minimise paperwork. Internal driving factors are the need for increased computing to do business, and the attitude of senior management and staff towards ICT (which, as indicated elsewhere, is already positive).

xi) A major negative influence is the lack of available ICT skills, as well as the costs of ICT, particularly in small and micro-organisations.

ICT FUNCTIONS WITHIN ORGANISATIONS

rating would in all likelihood have been higher. These technologies are not as yet widely used in the industry, and may explain the low rating in this survey.

xii) A number of existing models emerged: in the large organisations there were generally between 5-30 ICT support staff, with some multinationals providing an ICT unit at the global level with local support units at the national level. One respondent created a separate IT company wholly owned by the mother company. In the case of small and micro- organisations, all ICT functions are outsourced. Some organisations have created help desks that are either in-house or outsourced.

xiii) Reporting lines also showed some variations:

a. IT managers report to either the Finance Director, Office Manager, Business Excellence Manager, Chief Information Officer, IT Steering Committee or to the CEO with a place on the board;

b. The Divisional Information Officer reports to the Marketing and Innovation manager; or

c. The IT Management function resides in the Directorate of IT.

SECURITY

xiv) Most organisations have firewalls, back-up systems, protective filtering software, and surveillance systems, as well as policies for personnel conduct relating to the use of ICT.

xv) Various confidentiality systems were in place, particularly with regard to client information, but security regarding employee information was not as good.

DIFFUSION OF ICT INTO THE SECTOR

xvi) In general, this sector is characterised by being an early or early majority adopter of ICT for the development of new products, services or niche markets. This also applied to the use of e-mail and the Internet, although large organisations were the slowest adopters of this application.

xvii) The use of ICT to market services and products was seen as lagging behind on the national level, whereas the global biotechnology sector is seen as an early adopter in this area.

xviii) There is likely to be an increase in the adoption of ICT for R&D, particularly due to the implementation of the National Biotechnology Strategy. How this approach will impact on new commercial applications will depend on how well the industry and R&D organisations are prepared to collaborate.

xix) The emerging South African biotechnology sector acknowledges that it will not be competitive globally if the development and application of ICT does not keep pace with that occurring globally.

What Can The Biotechnology Sector Do To Better Exploit ICT?

- Ensure that, through the implementation of the National Biotechnology Strategy, the biotechnology sector's ICT and bioinformatics needs are effectively addressed.
- Form partnerships with ICT companies to identify new development opportunities such as software for biotechnology applications; communication systems between equipment and sophisticated visualisation systems for molecular modelling. In addition, initiate the provision of distance consulting services, identity preservation systems and more effective distance learning opportunities through the application of ICT.

- Develop a biotechnology portal for South Africa to enable more effective biotechnology information transfer and communication internationally and nationally.
- Work with government to ensure there is a raised level of awareness of the role of biotechnology and ICT in economic development.
- Work with government and the ICT sector to ensure more integration and development of novel applications.
- Include ICT in current tertiary level training courses that will lead to new qualifications covering both of these areas of expertise.

What Can The ICT Industry Do For The Biotechnology Sector?

- Bandwidth inadequacies (cost, capacity, availability, quality) in South Africa have to be addressed as a matter of urgency.
- In general, the ICT industry is not providing a high-quality service to the biotechnology end-users, nor is there understanding of the sector's particular needs, particularly for SMMEs. Service providers will need to address this issue and the ICT industry needs to regulate itself on the quality and efficiency of the service it provides.
- Interact and work with the biotechnology sector to encourage a convergence between ICT and biotech technologies and their applications.
- Offer more appropriate training courses and approaches.
- Utilise ICT applications more effectively in the drive to ensure the general public have an awareness and understanding of the technology so that future applications of the technology have public acceptance. Without public acceptance the biotechnology sector cannot develop in South Africa.

What Can Government Do?

- The government urgently needs to address bandwidth issues in partnership with the ICT sector. One respondent illustrated that competitiveness is hampered by excessive Internet costs by indicating that it is cheaper to fly return to London and pick up a tape of the human genome sequence than to transfer it here via FTP (transfer of 10Gb over 2 days = R28 000; return trip to London + tape = R7 000). Reducing Telkom's Internet pricing would have an immediate impact on competitiveness and affordability.
- The need to address assistance for SMMEs in particular was highlighted by numerous respondents. Government should look at incentive schemes that would make ICT more accessible to all, such as tax deductions or concessions for ICT hardware and software especially for SMMEs.
- More training is required at all levels. This issue should be addressed through the SETAs[2] for each sector. In addition, government could enter into partnership with ICT training providers to offer courses that fit the biotechnology sector's needs.
- Some respondents identified the need for more learnerships sponsored by government for post-graduates entering the biotechnology sector. More emphasis should be given to supporting learnership programmes that provide financial assistance and training both within the organisation

[2] The Skills Education and Training Authorities established by the government for various sectors in South Africa

as well as ICT training opportunities. This will help to ensure a workforce within the biotechnology sector that has well-developed ICT *and* biotechnology skills.

- Special post-graduate projects could be developed, which provide the opportunity for biotechnologists to work with information and communication technologists. These pilot projects would be aimed at developing new applications of ICT in biotechnology, new products and at improving communication between equipment and process. This in turn would stimulate small business development.
- To ensure that biotechnology is more accessible to all, the ICT sector, government and the biotechnology sector need to work together. Opportunities suggested by respondents as ways in which governments could be assisting ICT diffusion include:

  i) Providing on-line health centres at hospitals (Internet booths that inform patients of health choices);

  ii) Rural Internet user sites dedicated to health information and biotechnology;

  iii) Free e-learning opportunities;

  iv) Information distribution on ICT benefits to business;

  v) An ICT database and help-line desk;

  vi) Free Internet access terminals at high schools and libraries; and

  vii) Working with existing biotechnology associations to coordinate improved ICT diffusion into the biotechnology sector.

1. Background

1.1 Biotechnology as an Emerging Sector

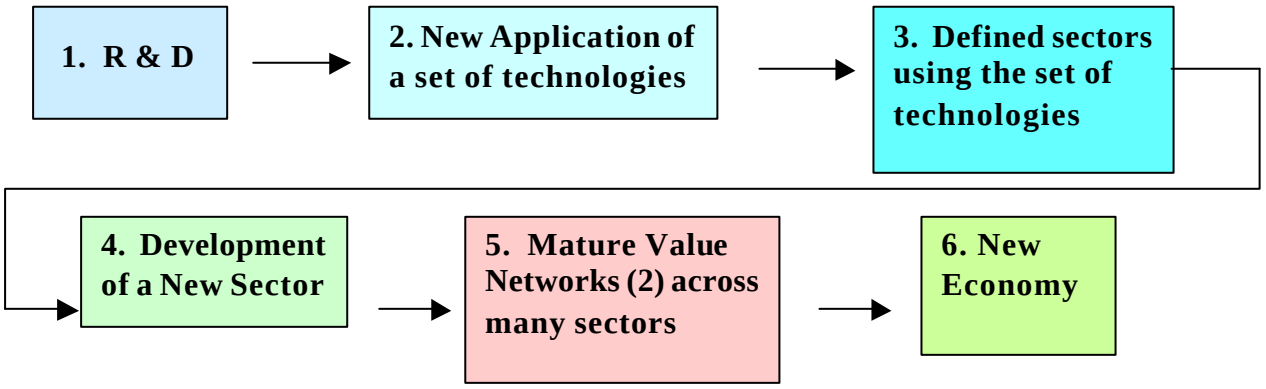
Biotechnology has evolved over the last 25-30 years into a powerful set of tools that is used in many sectors. It is referred to as a crosscutting technology. The role of biotechnology in the future will be vast and many predict that the next big advance will be the global development of a Bio Economy[3] [4].

Biotechnology has rapidly developed in North America and it could be said that the USA is entering the age of a bio-based economy. This prediction is confirmed by the recent Ernst & Young biotechnology survey (2002)[5] which found that the global biotechnology sector experienced its second best financing year ever and outperformed both high-tech and blue chip sectors. In 2000, the USA had 1 379 biotechnology companies of which 30 are defined as 'world leading'. Europe has 8 'world leading' biotechnology companies. Canada's biotechnology sector experienced dramatic growth with an increase in biotechnology companies from 227 in 1997, to over 400 in 2001. They now have two 'world leading' companies, each with a market capitalisation of more than US$1 billion. Many countries in the Asia/Pacific apply biotechnology to discover active ingredients in traditional medicines and to improve 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.

Government support for biotechnology is illustrated by their increased 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.

In South Africa the biotechnology sector is only beginning to emerge from Stage 2 as described in ***Figure 1*** below**.**

Figure 1. Progression* of a Technology to a Sector and then an Economy[6]



*This progression is not always linear

[3] Koch M. and Webster, J R (1999). *Bio-Economy – The Next Big Thing?* Transnet (MOT), 26 pp.
[4] OECD (2002). *The Application of Biotechnology to Industrial Sustainability- a primer.*
[5] Ernst and Young (2002). *Beyond Borders: The Global Biotechnology Report,* Ernst & Young, UK.
[6] Verna Allee, 2000. *Reconfiguring the Value Chain.* Journal of Business Strategy. Vol.21, No.4

South Africa now recognises the role of biotechnology in economic development with the government publishing a draft National Biotechnology Strategy in 2001[7]. The total spend on biotechnology R&D until 1997 was R100 million and is now estimated at approximately R200 million. There are no available estimates on the market size for biotechnology products or services, nor is there clarity on the exact nature, scope and definition of this sector. South Africa therefore does not have a defined biotechnology sector but rather defined sectors using the new set of technologies. The development of biotechnology even as a sector is very immature. **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.**

The biotechnology survey carried out by Webster and Koch (1998)[8] on behalf of the Council for Scientific and Industrial Research (CSIR) indicated that there were new applications of the technology (e.g. biosafety) and defined sectors using the technology in South Africa (e.g. medical and pharmaceutical, plant, food and beverage, environmental, chemical and mineral, veterinary). Very few new companies have developed in South Africa that can be said to be biotechnology companies, and those that have been initiated largely remain micro-sized or small. Many of the companies applying biotechnology in South Africa are multi-nationals however, some local companies are actively applying the technology. The roles of government, universities, research organisations, industries and stakeholder organisations have been identified by Webster and Koch (1998).

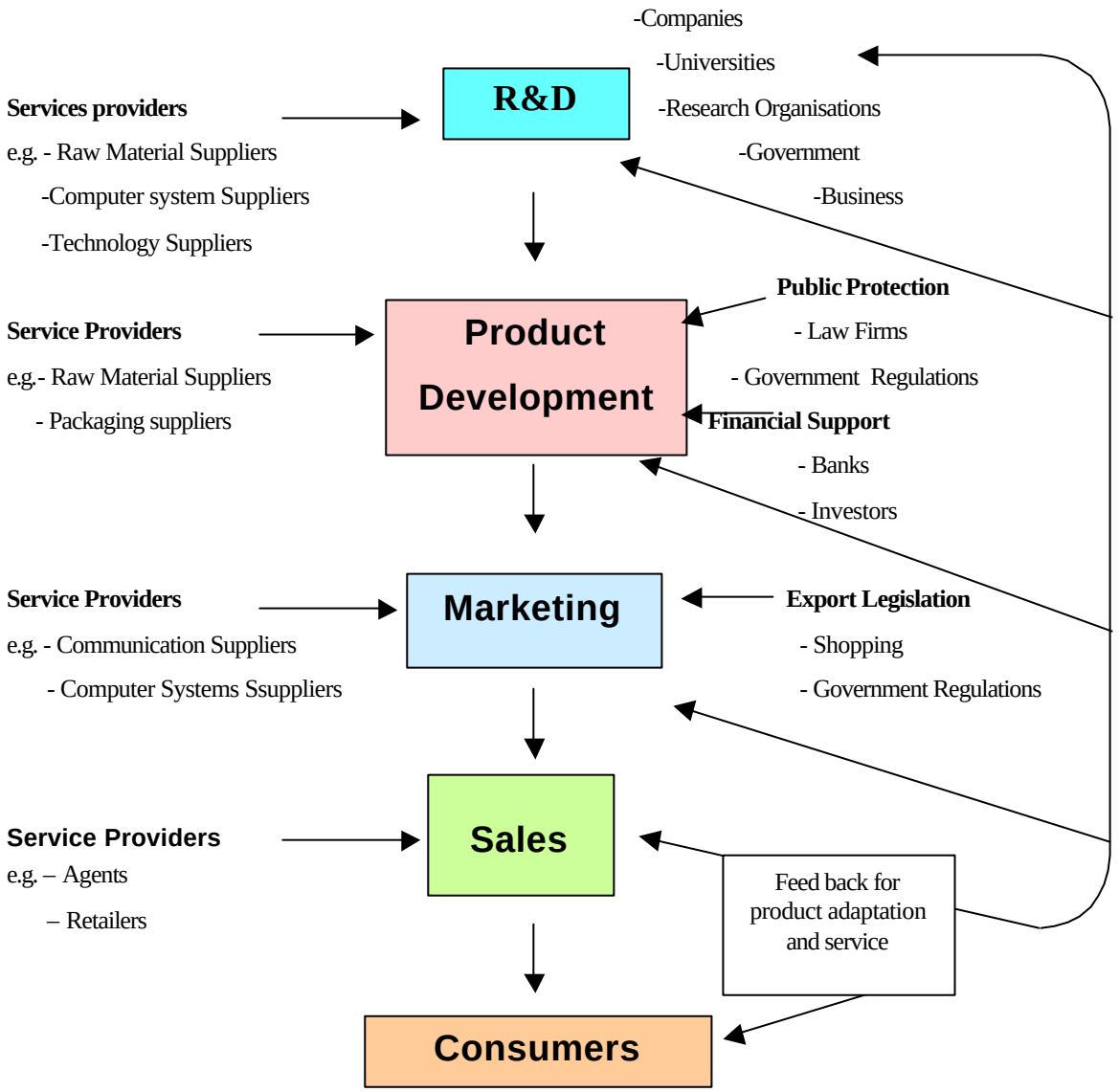
To understand the ICT diffusion into the sectors using biotechnology it is important to unpack a generic value chain for all sectors using biotechnology, and target both key areas of the value chain and key sectors applying the technology.

1.2 The Value Chain

The tangible value chain for biotechnology is similar for all sectors involved. The value chain can be depicted simplistically as shown in ***Figure 2 on the page following***.

[7] Department of Arts, Culture, Science and Technology (DACST) (2001). *The National Biotechnology Strategy – Draft, 2001*.
[8] Webster and Koch (1998). *Biotechnology Survey: A Situational Analysis of South Africa and Sub-Saharan Africa.* CSIR internal report.

Figure 2. The Generic Linear Value Chain for all Sectors (Without Intangibles)



1.3 Intangibles

These include the value added by other stakeholders such as trade associations, government through policy development and implementation, and shared collective knowledge across all stakeholders including international linkages and networks.

Both tangibles and intangibles are important in accessing a sector. This is particularly true if the final outcome of a study is to stimulate growth and increase value outputs. This can be done by:

- Adding value;

- Extending value to others not already using the technology; and
- Value conversion.

All these aspects apply to the issue of how ICT could be used in increasing the value outputs in biotechnology.

Biotechnology currently uses ICT for the following functions include:

- Standard business practices;
- Information exchange;
- Diagnostics and detection systems (includes biosensors, early warning systems);
- Imaging;
- Sequencing;
- Bioinformatics (Data collection, management, manipulation, application);
- Molecular modelling;
- Virtual experimentation;
- Robotics;
- Impact alerting services;
- Identity preservation systems;
- Nanotechnology; and
- e-Learning.

Biotechnology could not have developed to its current state without the diffusion and integration of ICT. As biotechnology evolves the volume of biological information is growing rapidly. The ability to apply collect, manage, manipulate and apply this resource depends increasingly on ICT capacity.

1.4 Current Status of Biotechnology in South Africa

South Africa has been involved with biotechnology research and development for over 20 years. Plant trials have been carried out under the interim and new legislation for over 10 years. There are approximately 110 groups, participating in 160 projects, from both academic and research institutions that are currently involved in active plant biotechnology. At present it is estimated that 45 companies are using biotechnology in food, feed and fibre. In all, there are over 500 biotechnology projects spread across seven sectors (biosafety, chemical, environmental, food, medical/pharmaceutical, plant, veterinary) in South Africa. The medical and pharmaceutical sector attracts the most research funding while the plant sector attracts the second largest amount.[9] 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

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

growth. This is reflected in relatively low levels of local technology innovation, and the industry status as lying in the early to late majority adopters in a number of areas.

One of the biggest challenges facing the South African biotechnology sector at the moment is the fact that the public are not informed. This has resulted in anti-activists making an impact by spreading misinformation that is creating negative public perception. Such developments in civil society could seriously hinder further development of the industry. Application of ICT is critical to addressing public awareness. Another key role for ICT will be wealth creation out of biological information. To achieve this, information access and sharing need to be encouraged and strengthened.

1.5 South African Biotechnology Policy, Regulations and Agreements

Policy. The Department of Arts Culture Science and Technology (DACST) developed a National Biotechnology Strategy in 2001. This document identifies a number of gaps that need to be addressed and suggests certain interventions to ensure that biotechnology plays a meaningful role in sustainable development. The recommendations are divided into two categories:

- New institutional arrangements; and
- Specific actions for government departments.

This includes the establishment of a Biotechnology Advisory Committee (BAC) under the auspices of the Cabinet's Economics Cluster, the responsibilities of which will include the implementation of this strategy, co-ordination of biotechnology R&D and alignment with national priorities. A key component of the strategy is the creation of a national bioinformatics facility and several biotechnology regional innovation centres (BRICs) to act as nuclei for the development of biotechnology platforms from which a range of businesses offering new products and services can be developed. The BRICs will be required to work in close collaboration with academia and business in order for the centres to become active nodes for the growth of the biotechnology sector. This document encourages government to complete a number of important revisions to the legislative and regulatory environment, in order for the strategy to be successful. The establishment of a Bioethics Committee and a revision of the Patents Act is also highlighted. In addition, it calls for careful attention to be given to the development of the appropriate human resources and to the public understanding of biotechnology. The strategy has not outlined in any detail policies or practical approaches to ensure the diffusion and integration of ICT into the emerging biotechnology sector.

Government funding for research and development, distributed through DACST, identifies both biotechnology and ICT as key areas for funding. *These funds do not specifically highlight the need to integrate the two areas.*

Regulation. The successful implementation of biotechnology requires public confidence in the technology and the safety of its products. To this end the South African government ran an interim biosafety assessment and decision-making process from 1990 to 1999 that lead to the establishment of the Genetically Modified Organisms (GMO) Act 15 (1997). The Act was implemented in December 1999 and activated the official national biosafety framework. This biosafety framework calls for risk assessment at all levels of GMO development and

commercialisation. It requires an independent scientific review of biosafety that details risk management and biosafety communication requirements. The Act calls for public input on applications and allows non-safety considerations in decision-making. National decision-making is undertaken by a multi-departmental committee that includes human health, agriculture, environmental impact, socio-economic and trade considerations and impact on labour.

In the interest of public information the Department of Health has produced draft regulations for the labelling of food derived from genetic modification (GM). The risk assessment of GMOs is required by the environmental impact assessment legislation, but is dealt with under the GMO Act. The Department of Environment and Tourism is the national focal point for the Cartagena Protocol on Biosafety and it is expected that Cabinet will agree to accede to this Protocol, which ensures the safe transboundary movement of living GMOs.

Agreements. In addition, South Africa has signed bilateral agreements with at least 12 countries that include co-operation on biotechnology. It is not clear what implementation is planned for these agreements.

2. Methodology

2.1 Questionnaire

In addition to the generic questionnaire used for all sectors, the biotechnology sector was asked to rate their management of information dissemination, their use of information as intellectual capital and their use of specific ICT-biotechnology interfaces. They were also asked to identify gaps in their ICT hardware and software, any specific ICT services and products they needed for biotechnology applications, and whether they were aware of any South African companies developing new biotechnology interests. The questionnaire is appended to this report.

2.2 Questionnaire Administration

The questionnaire was tested with two sub-sector groups before finalisation. Small changes were made in response to this input. The revised questionnaire was distributed electronically and by fax to 150 biotechnology groups in the country[10], which included government, research, industry and academic organisations. In addition, 50 key stakeholders were identified for personal contact and interviews.

[10] Based on the survey sample from Webster and Koch, 1998

2.3 Interviews

To ensure that the study included key stakeholders in biotechnology in South Africa a cross section was taken over sectors and over the value chain within sectors. The following related sectors were specifically targeted: Food and agriculture (including beverage); Pharmaceutical and medical (including veterinary); Industrial (including chemical, mineral and environmental). The in-depth interview mix is shown in ***Table 1.***

Table 1. Distribution of planned and actual questionnaire responses from the biotechnology sector

	Number of responses				
Organisation Type	**Large**	**Medium**	**Small**	**Micro**	**Total** Actual (and planned)
Companies	6	4	4	6	20 (28)
Suppliers	0	0	2	2	4 (6)
Sectoral Associations	3	0	0	1	4 (2)
Research Organisations	3	1	0	0	4 (3)
Academic departments	4	1	2	2	9 (4)
Government departments	0	0	1	3	4 (3)
Other (Investors, Key Internat. linkages)	0	0	0	2	2 (4)
TOTAL	**16 (34%)**	**6 (13%)**	**9 (19%)**	**16 (34%)**	**47**

These responses were from agriculture (13 replies); food (9); pharmaceutical and medical (8); industrial (4) and general (13). They reflect approximately 15 per cent coverage of the emerging biotechnology sector in South Africa.

2.4 Data collection process

Responses to the questionnaires were received by fax, e-mail and through telephone and personal interviews, individually or in focus groups. This data was entered into a spreadsheet and analysed to produce the trends present in the next section.

Very few stakeholders wanted to have personal interviews in their offices, believing the time did not justify this, when the information could be written and sent or given over the telephone. Many stakeholders felt the questionnaire was too complex and too time consuming to complete easily. None of these actually returned a questionnaire or made time for an interview. Several respondents were unsure of the long-term value of contributing to the survey as the 'government never does anything' after exercises like these. The success with obtaining replies and interviews was largely because the researchers knew many of the people on the target list. When the researchers did not know the target person, it was difficult

to obtain an interview or reply. In addition, many of the biotechnologist managers preferred to pass the survey onto ICT people in their organisations, filling in only the sector-specific questions themselves. Some respondents felt some of the questions required sensitive information that they would not release. This information differed between organisations.

3. Results, Analysis and Interpretation

To enable comparisons, the responses from large, medium, small and micro-sized organisations were separated in all data analyses.

3.1 Nature of the Biotechnology Sector

As detailed in the overview, the biotechnology sector is founded on large multinational organisations or local organisations that have developed a significant investment in biotechnology. Supporting this fairly sparse framework is a group of strong academic and research groups that will play an important role in delivering biotechnology products to address local needs. The government sector is very small, mostly reluctant partners in the technology, which they are called either to regulate or support. The fastest growing area in the sector is the suppliers. Initially suppliers were mostly involved in providing equipment and running materials for research and product development. Now this group includes ICT providers, technical consultants, legal expertise and professional associations looking after the interests of members collectively.

Responses to the questionnaire (***Table 1***) did not fully correspond to the original proposal due to the lack of interest by some companies, especially those within the industrial, and medical and pharmaceutical sectors. Academic departments responded well and the overall cross section of large to micro-sized groups was good. Only medium-sized groups produced a poor sample size (n=6).

An analysis of the data provided by the 47 respondents about their organisations also reveals some interesting ICT trends:

- The number of personal computers to employee ratio: 1:2 (on average of the information provided)
- The percentage of respondents with e-mail: 100%
- The percentage of respondents with Website addresses: 85%
- Involvement in ICTs: 44% of the respondents had a high or very high (meaning extensive with constant sophisticated usage) involvement in ICTs.[11]

[11] Rated as a 4 or a 5 on a five point scale.

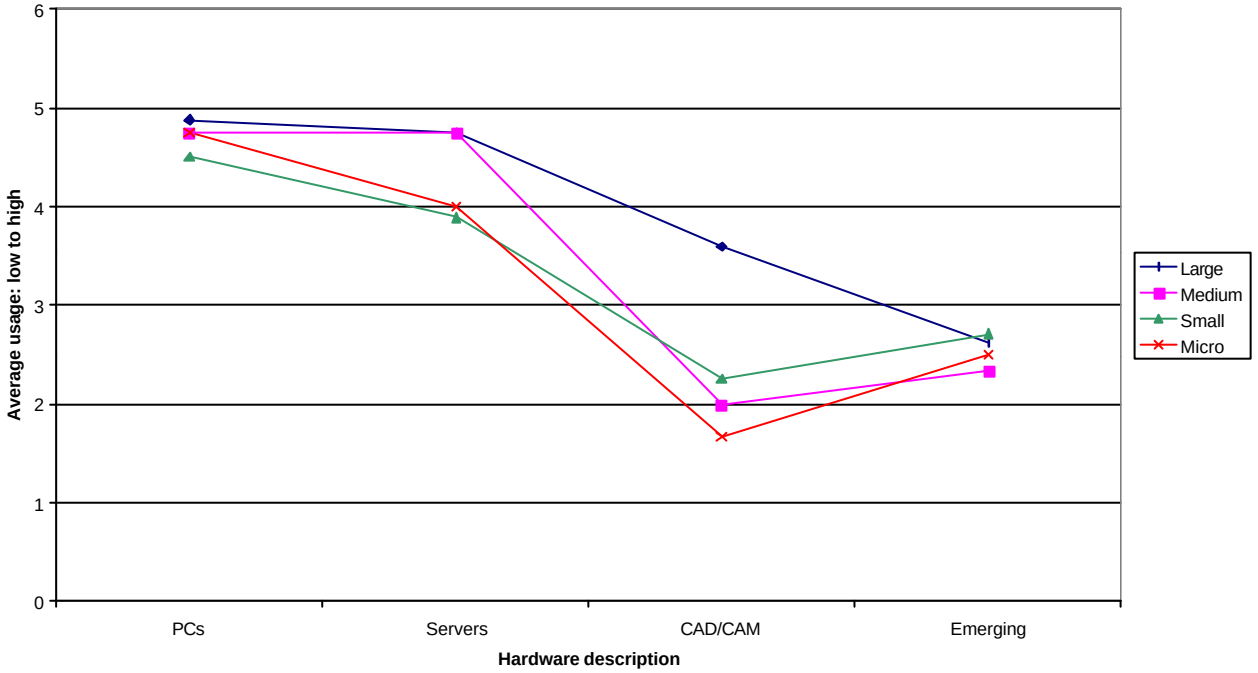
3.2 Characteristics of ICT Usage

For this section respondents were asked to characterise their organisations' use of ICT on a scale of 1 (no use at all) to 5 (fully utilised). The score of 0 indicated 'not needed' or 'do not know', but these data were excluded from the final calculations. The data were averaged for an indication of how ICT is used in different sized organisations in the sector.

3.2.1 Basic Technologies

The use of basic hardware by various sizes of biotechnology organisations is illustrated in ***Figure 3***.

Figure 3. Biotechnology ICT hardware usage across group size



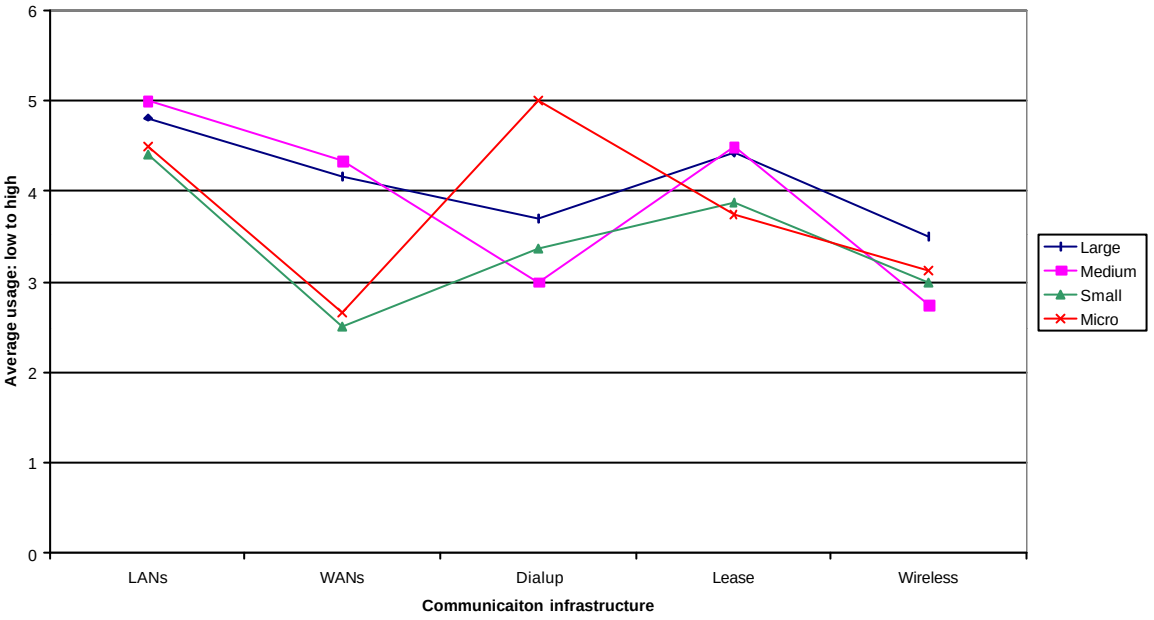
The biotechnology sector has a very high usage of personal computers and ICT hardware such as servers. The size of organisations was not a barrier to diffusion of basic ICT hardware. Emerging technologies such as sensing devices and robotics are not well used by all sizes of organisations (***Figure 3***). This suggests that organisations either do not have a need for these particular emerging technologies or could not afford to invest in them. However, our knowledge of this sector indicates that other emerging technologies are being used, such as micro-array, and technologies for proteomics and genomics.[12] Presently these are being purchased predominantly by South African research organisations and universities; very few companies are as yet investing in these expensive technologies.[13]

[12] Further information on the need for these new technologies can be obtained from the National Bioinformatics Facility Survey at *www.sabi.ac.za/surveys*
[13] These technologies can cost as much as R 5m to purchase.

The use of CAD/CAM systems is primarily by large organisations; this particular technology is not of great use in the biotechnology sector and it is possible that it is used in 'non-biotechnology' areas in the large companies.

Use of communication infrastructure is illustrated in ***Figure 4.***

Figure 4. Communication infrastructure across group size

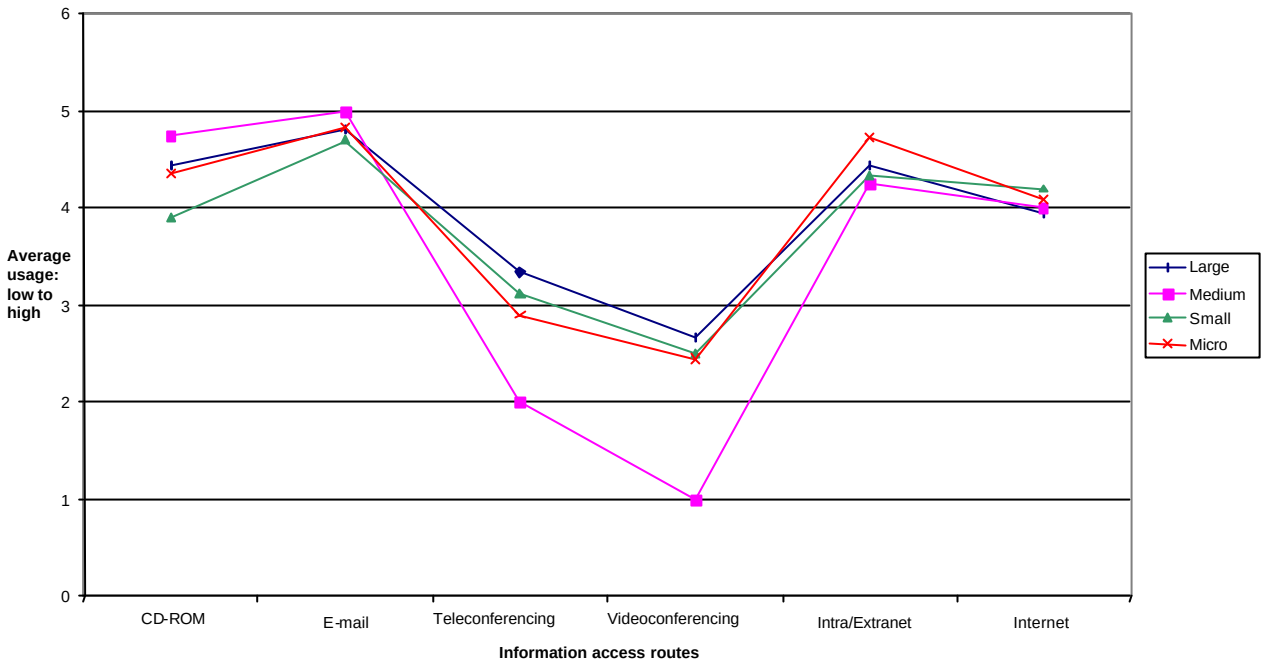


Local area networks (LANs) are well utilised by large, medium and small organisations. As could be expected, wide area networks (WANs) are used more widely by large and medium organisations than smaller organisations. This sector is characterised by strong virtual networking and collaboration at the national and international levels. This would require the use of such technologies, in addition to e-mail and the Internet (See also ***Figure 5*** below).

Many of the organisations surveyed have branches throughout the country, or linkages to international branches since they form part of a multinational company. While large and medium groups mostly use Telkom leased lines for their communication systems, they also use dial-up lines. These are often used by staff who work from home.

Information acquisition and communication is illustrated in ***Figure 5***.

Figure 5. Information acquisition and communications across group size



All sized organisations have a high usage of e-mail, the Internet, intra or extranets and CD-ROM (***Figure 5)***. The Internet was seen as providing useful content such as on-line journals, patent information, and databases (e.g. sequencing databases)

A surprising result was the low level of teleconferencing, even though it has been adopted as effectively by micro and small organisations as by large organisations. Six respondents commented that there is not enough use of teleconferencing and videoconferencing particularly for communications and building relationships with customers, - this was identified as area requiring more emphasis in their organisations. Considering the international linkages that seem critical to the functioning of this sector, there appears to be an opportunity for development of this technology.

The high use of CD-ROMs in this sector is of interest. Due to the data- and knowledge-intensive nature of the sector, a large amount of information is circulated across the value chain. The slowness of the Internet and ineffective bandwidth availability mean that information is frequently packaged on CD-ROMs. Examples include research results, information on impact assessments of GM products, etc. The medium is also used extensively in educating suppliers and distributors in the value chain. Due to the low levels of ICT literacy at the consumer level, this technology is not yet extensively used, for example, to reach farmers, or agents who are working directly with this end of the value chain.

The communications problems on the African continent have also led to the use of 'low-end' technologies such as diskettes, sometimes as many as 100 at a time for the packaging of specific information products, and CD-ROMs.

In response to the question on where the most emphasis is needed in the respondents' organisations, the majority of respondents identified increased capacity in use of the Internet and communications as an area that required further development:

"Info acquisition and communications – ability to communicate effectively and efficiently on a global basis with particular reference to relationship networking and sourcing information."

"Networks among biotech stakeholders in SA, networks to international biotech stakeholders."

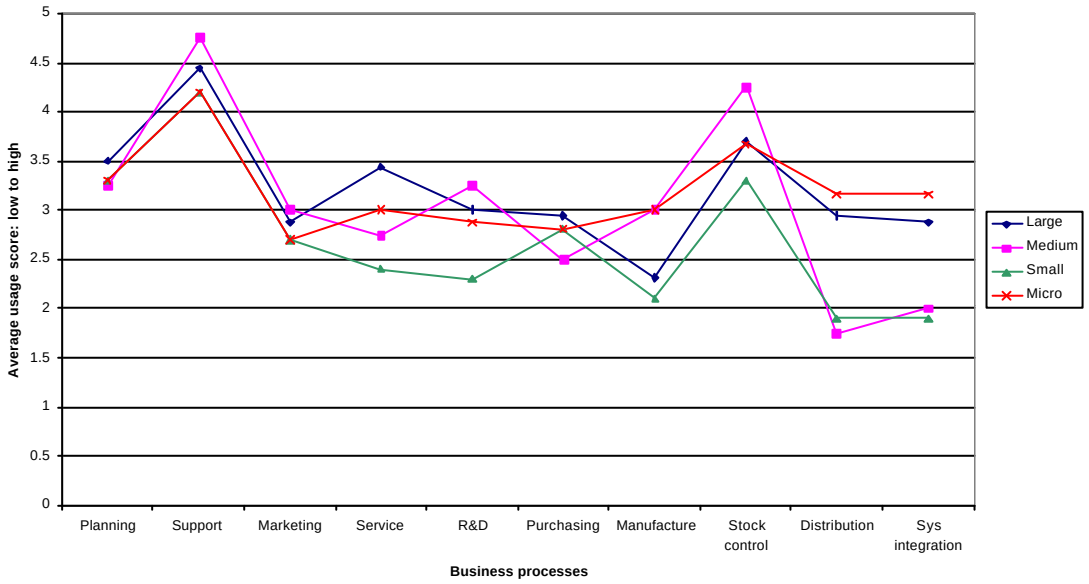
"Linkages between RSA and international systems to be improved; upgrading standard of RSA systems."

"Stable, high throughput Internet work; Information acquisition and communication."

3.2.2 Applications

An indication of ICT applications used by the sector to streamline business processes is given in ***Figure 6***.

Figure 6. Streamlining business processes

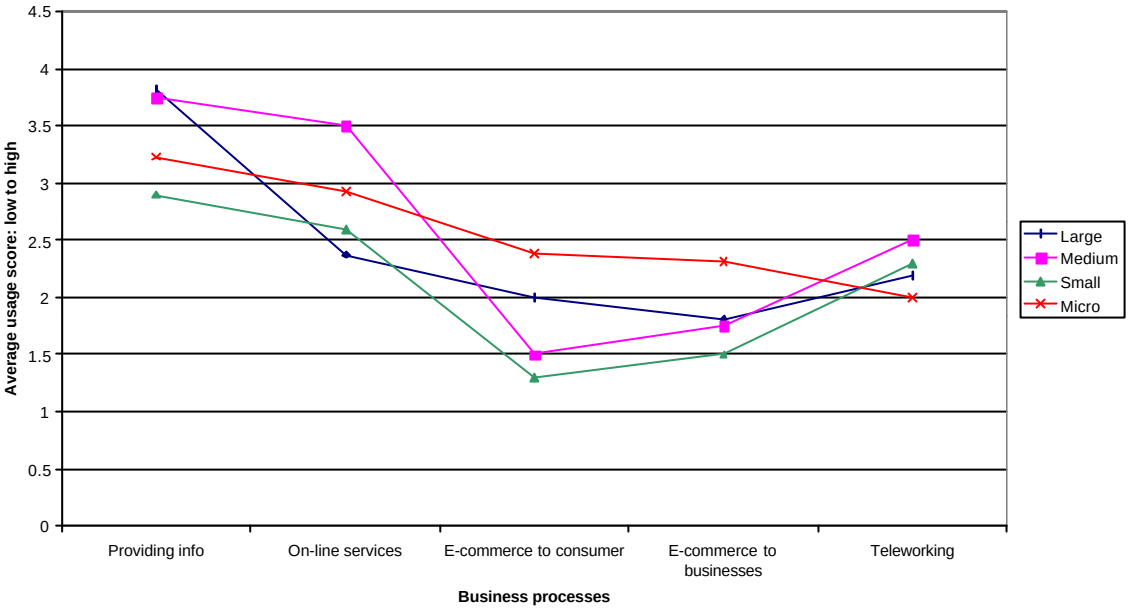


Planning and strategy ICT applications are well used by large, medium, small and micro sized organisations (***Figure 6***). All organisations, except medium-sized ones, under-utilise ICT applications for marketing and sales. Many of the respondents noted that there was a need to improve the application of ICT for marketing and communications with the clients. Considering the fact that the biotechnology sector is still strongly focused on R&D, it is interesting to note that the use of ICTs to *manage* is rated relatively low. Research would be

needed to investigate this in more depth, but these results do indicate that an area that requires attention could be the setting up of technology management systems.[14]

Mechanisms to transform business are presented in ***Figure 7***.

Figure 7. Transforming business processes across group size



The relatively high ratings given to the use of ICTs to provide information relates strongly to the fact that the biotechnology is heavily reliant on data and knowledge management. A comment made by one respondent is revealing:

> *"[The] generation of increasing amounts of data through the genomics /post-genomics revolution will require ever more sophisticated ICT solutions. The line between biotechnology and ICT is critical."*

Several respondents noted the need for better communications through the Internet (e.g. Web-based marketing), and e-commerce systems to market themselves better, and provide services to their customers both nationally and internationally. This is born out by the under-utilisation of e-commerce by most organisations, except micro-sized (***Figure 7).*** The higher use of e-commerce by the micro players may indicate their use of ICTs to level the playing field.

One of the main barriers to the broader use of e-commerce (i.e. customer relationship building and services) is that some of the present or potential customers are not using ICT systems themselves. This was particularly mentioned by organisations dealing with consumers as part of their value chain e.g. farmers, agents in the agricultural sector.

[14] To our knowledge, for example, the CSIR is the only research institution that has an extensive ICT-based technology management system in place.

An analysis of comments from respondents seems to indicate that the uncertainty around security issues e.g. the controversial Electronic Commerce Bill and its implications, are one of the reasons for slow adoption of B2C and B2B e-commerce.

The relatively high use of online services is probably attributable to the use of online ordering systems and access to subscriber-based databases.

Other barriers or needs experienced by the biotechnology sector are:

- Inadequate bandwidth provision (this was highlighted by at least half of the respondents as a major constraint);
- Download speeds for high data volumes are inadequate;
- Cost of adequate bandwidth prevents local companies from being more competitive – one respondent comments that

> *"Access and manipulation of datasets via the Internet was not possible because of bandwidth costs and [was] a major inhibitor of competition with overseas technologists";*

- Internet access is not good. It is often easier to ask questions on e-mail than to go to the Internet for answers;
- Telecommunications are slow and not accessible in peak hours; access to the rest of Africa is very poor;
- Lack of in-house knowledge and understanding of ICT applications;
- Weak and inadequate technical support - the available ICT skills are not adequate to support the highly specialised requirements in biotechnology;

> "*We bring in significant international funding and our GREATEST frustration is the lack of good ICT support. We need easy access to experts who can troubleshoot, repair, upgrade and advise on daily ICT need and special applications needed to work smarter at new jobs."*

- Affordability of technical support in small and micro organisations;
- Lack of affordable ICT applications and systems for small and micro-sized businesses;
- Search engines are often inadequate and unsuccessful; and
- Computers that are affordable are not big enough to analyse the data used by many organisations.[15]

The most frequently highlighted issues were poor service from service providers, particularly Telkom, the limitations of Telkom, particularly bandwidth, and the need for greater understanding and use of ICT applications in the sector. Respondents believe an

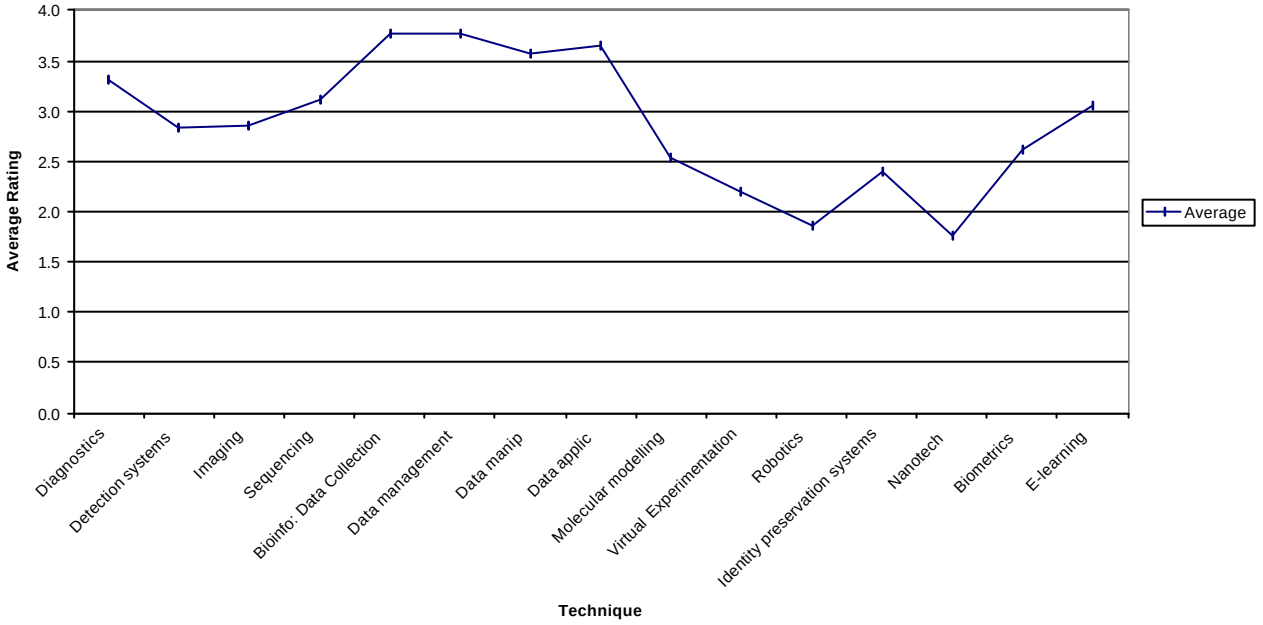
[15] This comment was particularly heard from the research community.

increased diffusion of ICT would result in more competitive interactions by South African organisations with their international customers and partners.

The use of ICT systems in streamlining business processes in the biotechnology sector is high for business support activities such as finance, accounting, data management, personnel management, payroll activities, and training. The use of ICT systems for strategy and planning activities is also high, but use for manufacturing and process control is low particularly for micro-sized organisations. Whilst many companies use ICT systems such as Websites to provide information, the use of interactive services was low and on-line business systems even lower. Teleworking is also not well used.

The use of biotechnology-specific ICT applications is illustrated in ***Figure 8***. For these data respondents were asked to rate their use of specific biotechnology techniques that require ICT interface for data collection and analysis. The scoring was: 1=not needed; 2=non-existent; 3= embryonic; 4= established; 5=common.

Figure 8. Use of biotechnology techniques



There is a growing usage of bioinformatics technologies (data collection, data management, data manipulation and application) in the biotechnology sector ***(Figure 8***). Virtual experimentation, robotics and nanotechnology are relatively poorly used and this possibly reflects the immaturity of the local sector. However, the embryonic nature of e-learning in the sector is possibly a result of the recent increase in biotechnology and bioinformatics distance learning opportunities over the last 12 months.

3.2.3 ICT Spending

Respondents were asked to assess their ICT expenditure compared to the expenditure norm of others in the South African biotechnology sector and of their organisations' ICT expenditure. The scoring options for these two data series were:

1=much less than the norm;	4=more than the norm;
2=less than the norm;	5=much more than the norm;
3=about the norm;	0=don't know

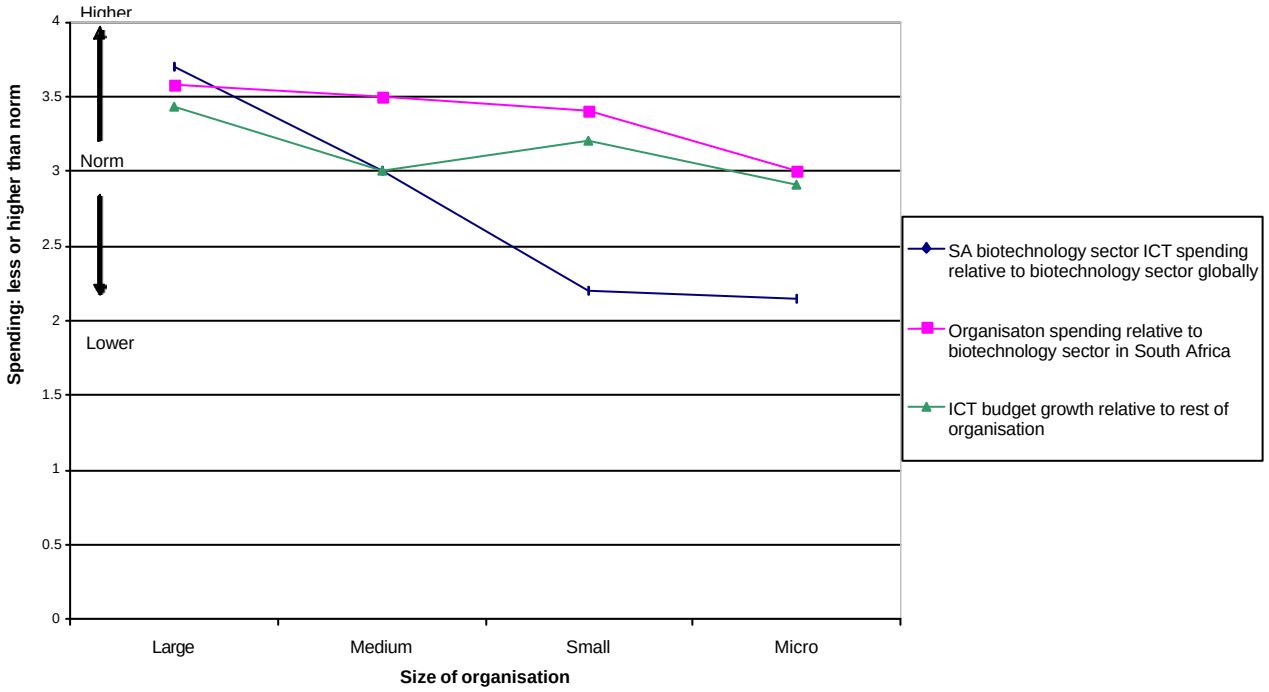
.

Respondents were also asked to rate how their ICT expenditure was growing relative to other areas in their own organisation. The scoring for this was:

1=much more slowly	4=more quickly
2=more slowly	5=much more quickly
3=about average	0=don't know

Figure 9 illustrates the respondents' assessment of their ICT expenditure compared to others in their sector, to ICT expenditure in their organisation and how their ICT expenditure is growing compared to other departments in their organisation.

Figure 9. Comparative ICT spending patterns across organisation size



Large organisations in the biotechnology sector perceive their spending to be more than normal on ICT hardware and software applications, relative to the global sector, whilst small and micro-sized organisations spend less than the norm in the global sector (***Figure 9***). This is probably because their international counterparts have stronger currencies, better access to capital and more government support to purchase the extremely expensive software and

hardware required.[16] Within the organisations, all spend the norm or above the norm and budgets for ICT are growing within small and large organisations. This would be expected, as the biotechnology sector cannot operate without ICT systems and applications.

3.2.4 Sources of ICT Information and Training

To collect these data respondents were asked to indicate their use of information and training sources with the following scoring system:

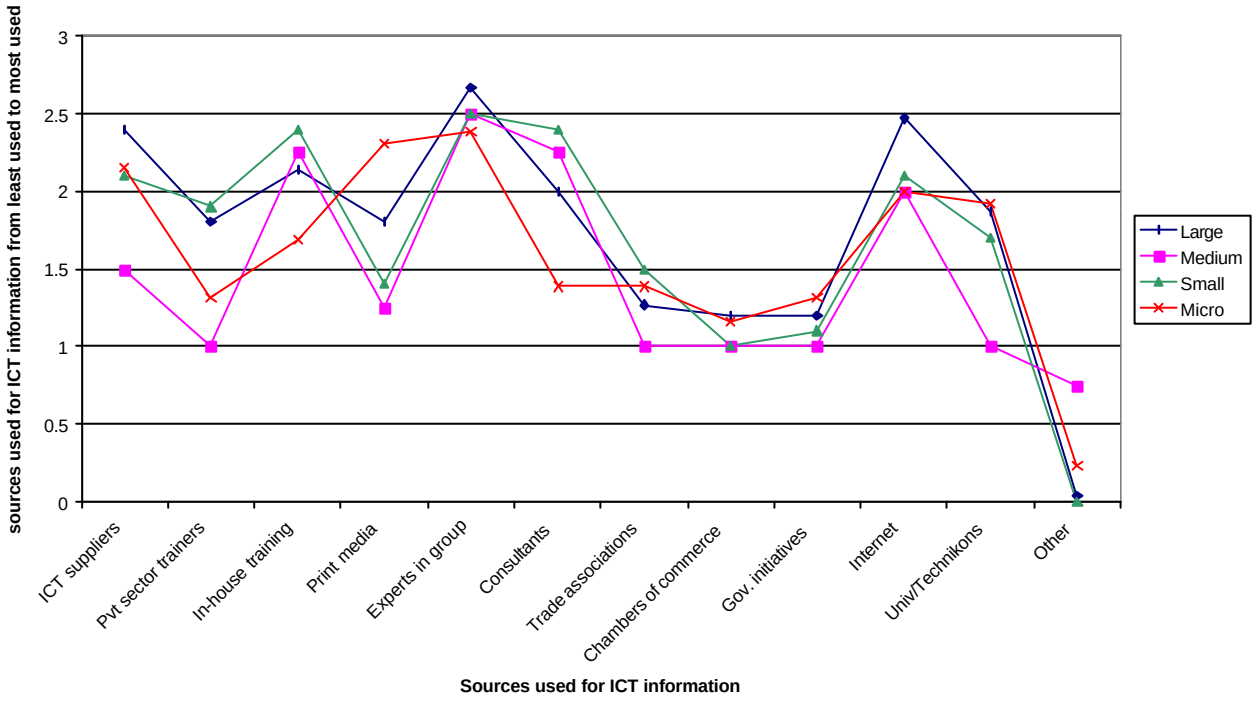
1 = sources least used or not used at all

2 = sources sometimes used

3 = sources most used

Data collected on common sources of ICT information are presented in ***Figure 10***.

Figure 10. Sources of ICT information across organisation size



ICT information sources. Most respondents indicated that they obtain their information on ICT systems and their use from experts within their organisation or from ICT suppliers, and also from in-house training programmes or universities and technikons. The Internet is a source of information used by all organisations e.g. access to online bio-informatics courses, sequencing programmes, new software programmes. Trade associations, chambers of commerce and government initiatives are not widely used by organisations. This is an area

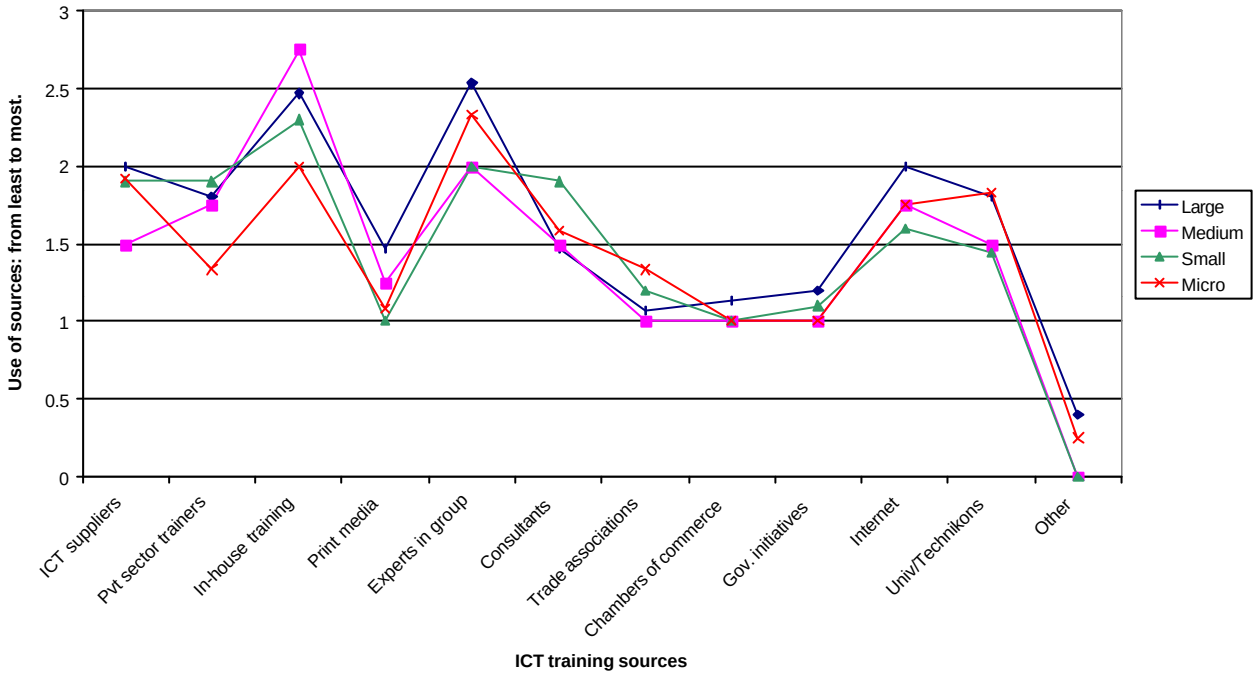
[16] The response from one interviewee referred to the fact that software cannot be treated as Capital Expenditure in South Africa, yet the expense of biotechnology software is generally as high, if not higher than the hardware, and can become redundant in an even shorter space of time.

that requires more emphasis as it is recognised that these organisations can provide a role in stimulating ICT diffusion and business development.

In general, the use of various sources of ICT information is quite low for such a knowledge-intensive sector. This can probably be partially explained by the fact that most available sources contain little relevant information on bio-informatics.[17]

Common sources of ICT training are given in ***Figure 11***.

Figure 11. Sources of ICT training across organisation size



ICT training sources. A similar pattern to that observed for ICT information sources was evident for ICT training sources (***Figure 11***). Most respondents source ICT training from experts within their organisations, in-house training programmes and the Internet. ICT suppliers were also rated high as a source of training.

In general, respondents from all size of organisations identified the need for more training. The most common barriers to training are time and money. Some organisations are starting to use e-learning and simulator programmes are used to some extent. Respondents were not aware of government initiatives in training, except for a one-year Masters programme in bioinformatics supported by the National Research Foundation (NRF) and an initiative for bioinformatics development initiated by the Medical Research Council. The South African National Bioinformatics Institute (SANBI) was identified as a good resource for the biotechnology sector for information and assistance related to bioinformatics.

[17] The National Biotechnology strategy has instigated a specific study to research this need in more depth for South Africa.

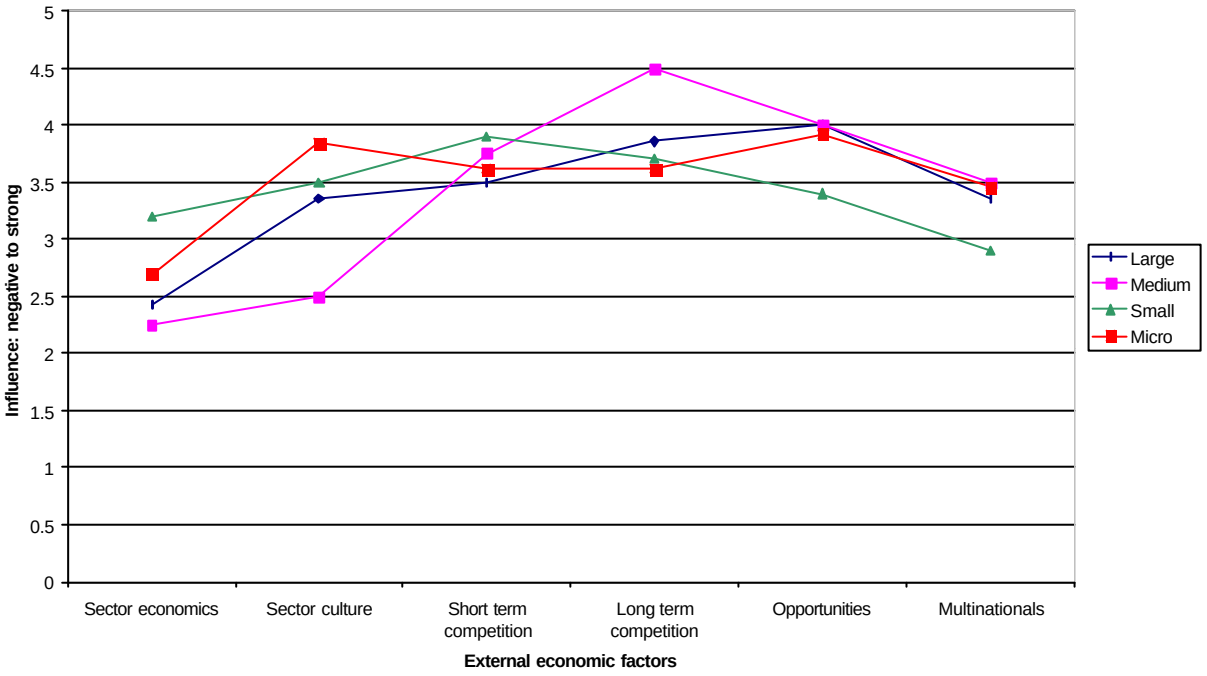
3.2.5 Drivers and Barriers to ICT Adoption

Respondents were asked to identify factors that most influenced ICT adoption in a positive way (drivers) and in a negative way (barriers). The scoring for this section was:

1 = strong negative influence (barrier)
2 = negative influence;
3 = no particular influence or not relevant
4 = positive influence
5 = strong positive influence (driver)

The responses to questions about drivers and barriers to ICT adoption are presented in ***Figures 12 – 14***. ***Figure 12*** presents the external economic factors that affect ICT adoption.

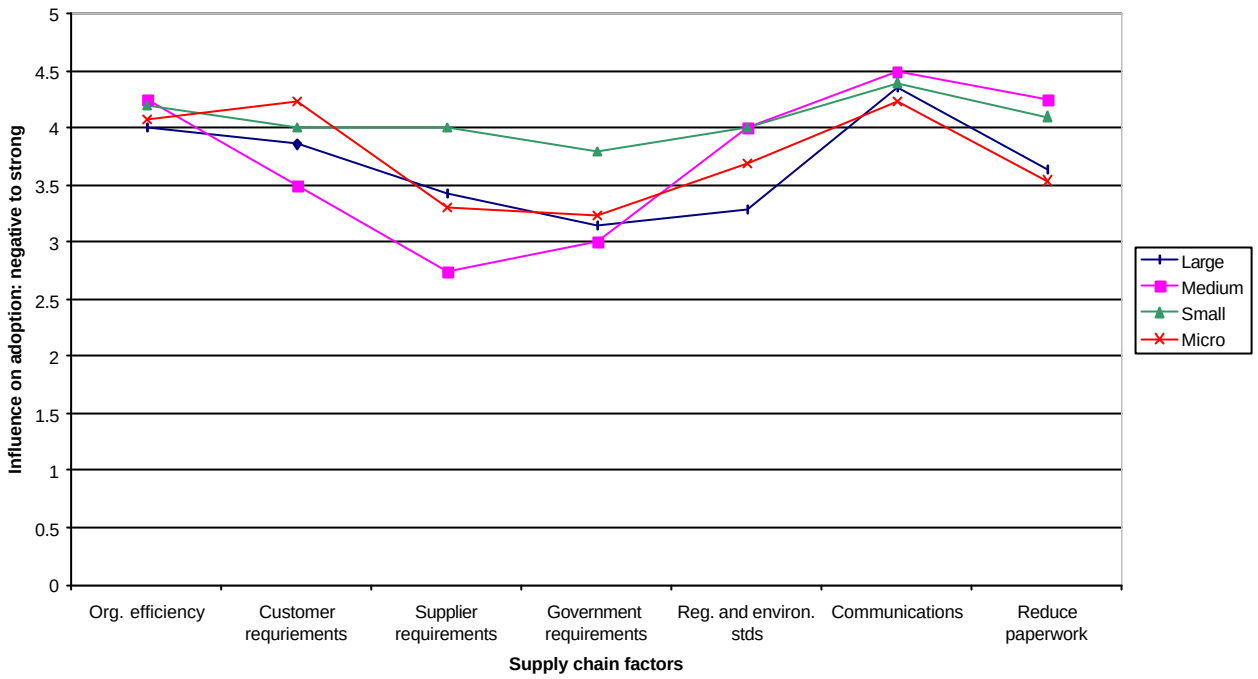
Figure 12. External economic drivers and barriers to ICT adoption



The external economic factor seen as the most important barrier to the adoption of ICT is the general economic conditions of the sector, ***Figure 12***. The strongest drivers are the expected increased competition in the short and medium term and the new opportunities for business development through ICT. It is interesting to note that on average most organisations identified that the sector's culture and attitude to ICT was a positive influence. This was not so for the medium sized organisations, but the results may reflect the small sample size.

Figure 13 presents supply chain factors that affect ICT adoption. The relatively high range of values recorded seems to indicate a strong awareness of the benefits of ICTs across the value chain.

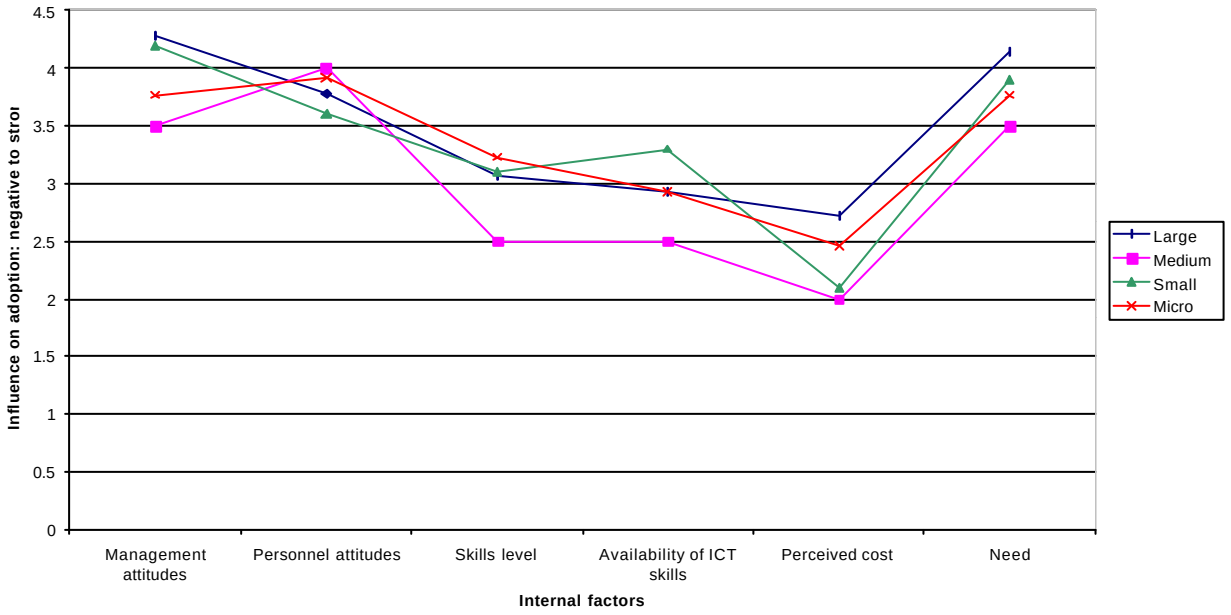
Figure 13. Supply chain drivers and barriers to ICT adoption



The supply chain factors that are seen as the strongest positive influence in adopting ICT are the need to: improve communication, respond to customer requirements; respond to national or international regulatory or environmental standards; increase organisation efficiency and minimise paper work (***Figure 13***).

Figure 14 presents internal factors identified as having an impact on ICT adoption.

Figure 14. Internal drivers and barriers to ICT adoption



The internal factors (***Figure 14***) that provide a strong positive influence on the adoption of ICT are the need for increased computing to do business and the attitude of senior management and staff towards ICT. Although not strongly reflected in the graph, the comments from respondents indicate that the availability of *appropriate* ICT professional skills is seen as the most important negative influence. Some comments reflect this concern:

> *"Need for RSA to promote closer interaction between ICT and Biotech."*
>
> *"Lack of knowledge of ICT systems and their application."*
>
> *"Bio-informatics – too few people who can link across disciplines."*
>
> *"Interfaces between ICT and Biotech very important."*
>
> *"We try to fill gaps with UNIX/LINUX systems, contracting [a] very specialised database consultant and with [a] great systems administrator."*

Small and micro-sized organisations identified perceived costs of ICT as a barrier to adoption.

Respondents were asked about who handles ICT functions in their organisations. While most large and medium organisations reported having an internal ICT function, the structures and reporting approaches differed. Some large companies have between 5 to 30 ICT support staff, while some multinationals have a whole ICT unit at the global level and a sub-unit with an IT manager and support personnel nationally. One respondent has spun off its support group as a separate company wholly owned by them. This company provides support services to their company, but is also able to offer services to other organisations. Other, mostly small and micro-sized organisations outsource all ICT functions. Some organisations have a help-desk, which is either in-house or outsourced.

The options for reporting systems are as follows:

- IT Manager reports to either the Finance Director, Exco (Office Manager), Business Excellence Manager, Chief Information Officer, IT Steering Committee or to the CEO and sits on the board;
- The Divisional Information Officer reports to the Marketing and Innovation Manager; or
- The IT management function resides in the Directorate of Information Technology.

In response to questions about security of the organisation's data and information, most organisations were very concerned and indicated varying degrees of how well security is managed. Most organisations have firewalls, back-up systems, various surveillance systems, protective filtering software and personnel rules for conduct associated with ICT systems. Confidentiality of personal data was rated of high concern in most organisations. Various

confidentiality systems were in place, however some respondents indicated that while client confidentiality was of high concern, privacy of employee information was not as good.

3.2.6 Diffusion of ICT into the Sector

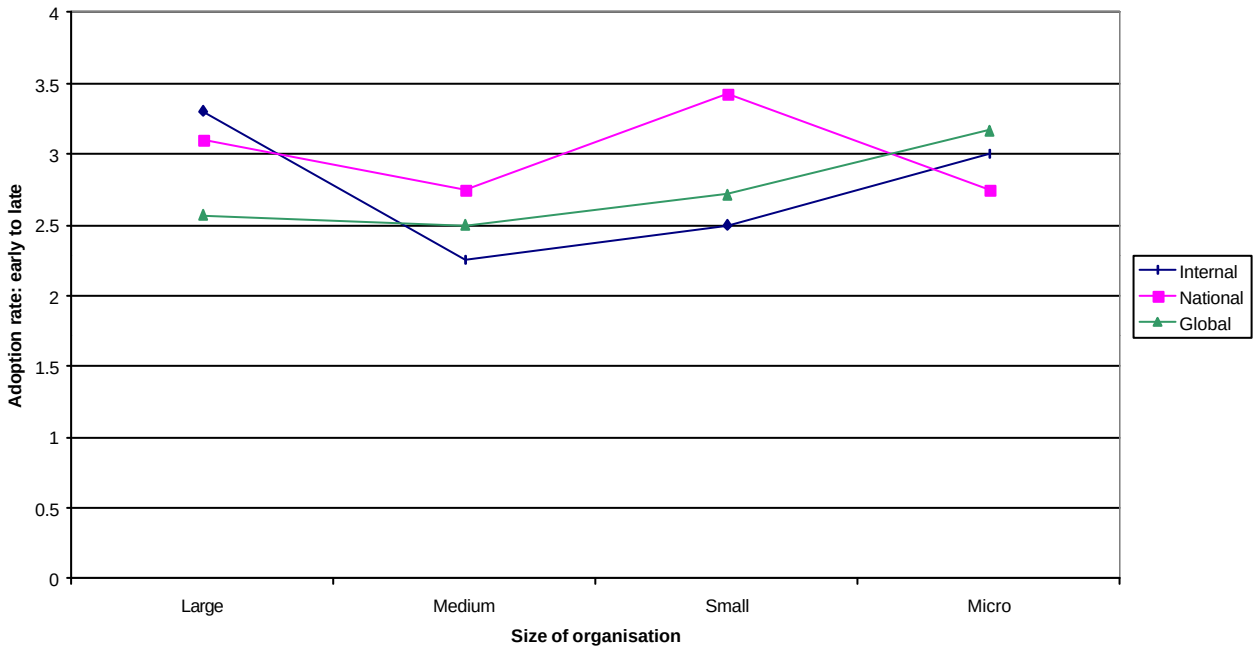
Data for this section was collected by asking respondents to rate the adoption category into which their organisation fell, within the organisation, compared to the national biotechnology sector and compared to the global biotechnology sector, for a range of business applications. The scoring was:

1 = an innovator (among the first few per cent to adopt ICT)
2 = an early adopter (among the next 10-15 % to adopt ICT)
3 = an early majority (among the next 30-40 % to adopt ICT)
4 = the late majority (among the next 50-90 % to adopt ICT)
5 = a laggard (among the last few per cent to adopt ICT)

Figures 15 to 19 illustrate the respondents' assessment of rate of adoption of ICT into the biotechnology sector relative to their own organisation, the sector in South Africa and the sector internationally. These graphs consider adoption rates (diffusion) into various areas of business. In general, the profiles indicate a sector that falls into the early to late majority, which reflects the sector's heavy dependence on the import of international technologies and a follower of such trends. On the whole, the industry cannot be classified as highly innovative.

Figure 15 considers adoption rates in product and service innovation.

Figure 15. ICT diffusion across organisation size for product and service innovation
(Using ICT to develop new products and services or exploit market niches.)

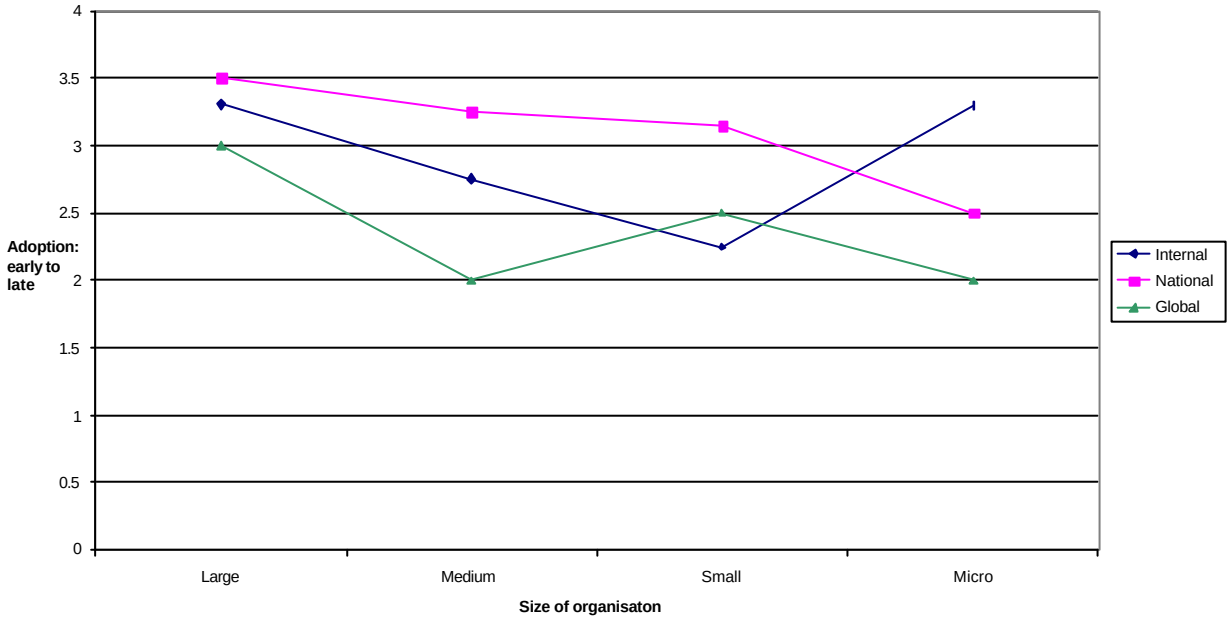


Large, medium and small companies identified the adoption of ICT in developing new products and services or exploiting new niche markets as early for the global biotechnology sector (***Figure 15***). This is a true reflection, as the biotechnology sector globally could not develop without the application of ICT hardware and software. As noted in the overview, the relationship of the ICT sector to the biotechnology sector is critical and is a limiting factor. IBM believes it will eventually become a biotechnology (or 'life science') company, as its new developments will be driven by the biotechnology sector. Conversely the biotechnology sector cannot reach its potential without new ICT developments and applications. In general, respondents from organisations of all sizes believe that their sector and their organisation were either early adopters or early majority adopters of ICT to develop new products, services or niche markets (***Figure 15***).

Figure 16 considers adoption rates (diffusion) into market innovation.

Figure 16. Diffusion of market innovation across organisation

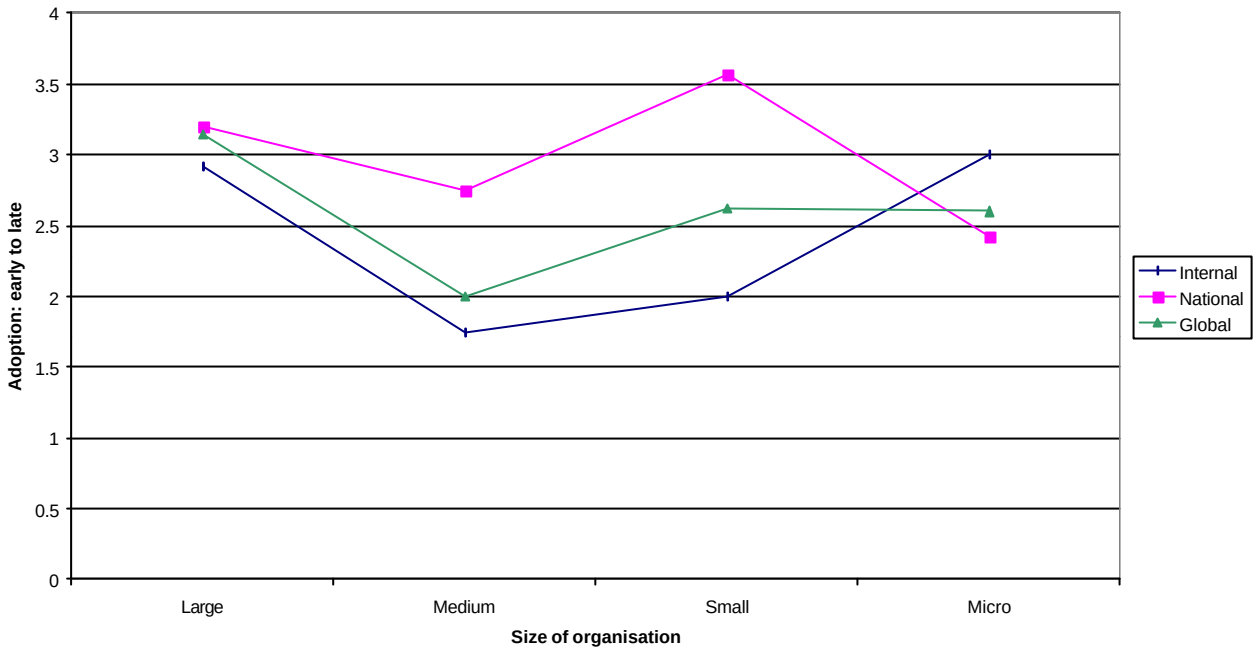
(Applying ICT and especially Internet to create new channels for marketing and products and services



Large organisations were early to late majority adopters of ICT applications for marketing their products and services at the organisational level and these respondents identified their sector as an early majority adopter at the global level (***Figure 16***). Medium, small and micro-sized organisations identified the global biotechnology sector as an early adopter of ICT to market products. It is of interest that small organisations see themselves as innovative marketers – possibly the South African characterisation of these players as very focused and operated in very narrow niche markets may have 'forced' them into using ICTs to level the playing field

Figure 17 below considers adoption rates (diffusion) into various administrative processes.

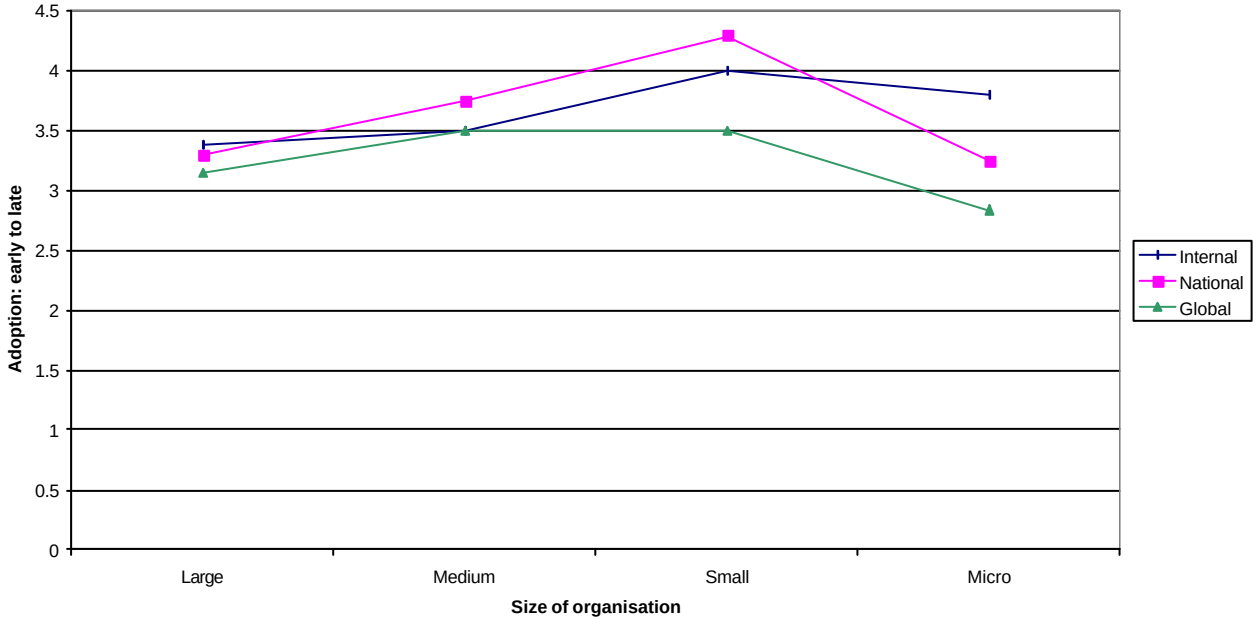
Figure 17. Diffusion of ICT into administrative process management
(Using Intranets and the Internet to improve communications, especially via e-mail and Web access.)



Using the Internet and intranets (especially e-mail and Web pages) was adopted early by most organisations to improve communications for business administration (***Figure 17***). It is surprising that the sector sees itself as very innovative in this area – possibly the lack of available benchmarking data may attribute to an unrealistically high rating, but no conclusion can be drawn here without further research.

Figure 18 considers adoption rates (diffusion) into relationship management.

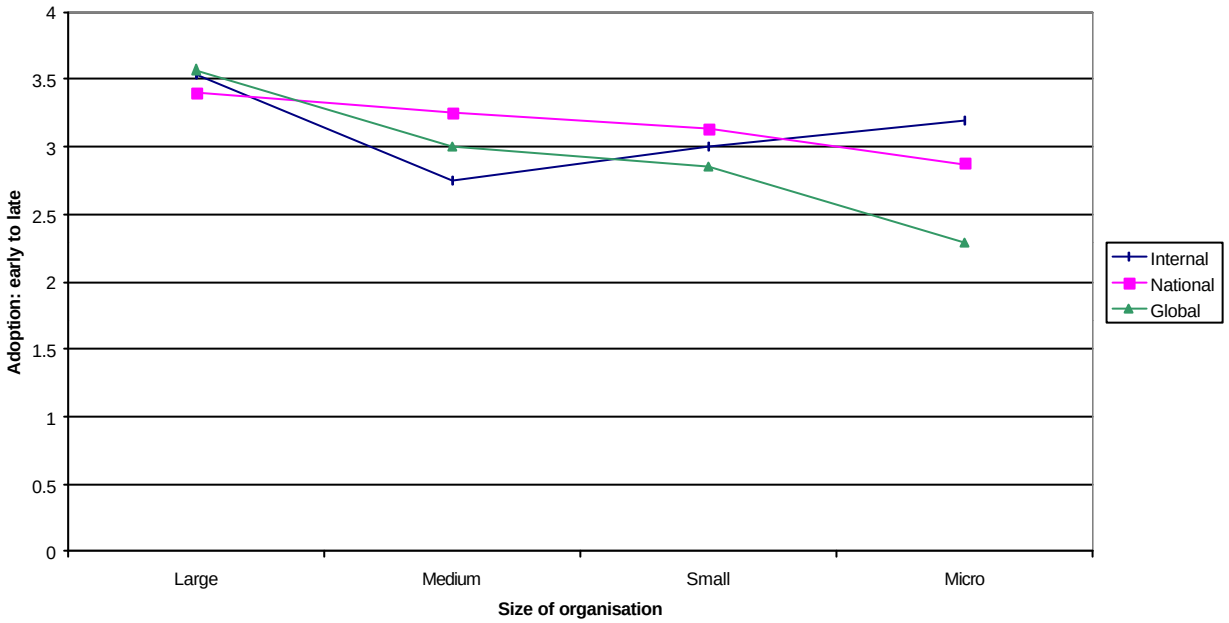
Figure 18. Diffusion of ICT into relationship management
(Using Extranets, the Internet and Virtual Private Networks to create closer links with other stakeholders, especially for EDI-based ordering and invoicing and 'just-in-time' production.)



Most organisations were early to late majority adopters of extranets and virtual private networks for relationship management (***Figure 18***). The use of the Internet to provide expertise at a distance was adopted most rapidly by micro-sized organisations, while large organisations were the slowest adopters of this application. The generally low levels of diffusion corroborate earlier statements relating to an increased need in the sector to address relationship management, particularly with customers.

Figure 19 considers adoption rates (diffusion) resource management.

Figure 19. Diffusion of ICT into resource management
(Using the Internet to provide or obtain expertise at a distance, like remote consultation, health diagnostics, distance learning and education.)



While the use of the Internet is low for all organisations for obtaining expertise at a distance, like remote consultation, health diagnostics, and distance learning these areas were highlighted by respondents as a growth area for the emerging biotechnology sector. Through the establishment of a national approach to bioinformatics (from the implementation of the National Biotechnology Strategy) these services should be offered in South Africa in the future. It should be noted that distance learning in Bioinformatics is available both nationally and internationally.

3.2.7 Expected Trends in Applications and Diffusion

The adoption of ICT into the biotechnology sector will continue and expand as the biotechnology sector develops. There will be an increase in the adoption of ICT for research and development, due to the implementation of the National Biotechnology Strategy, which highlights the establishment of a national bioinformatics resource to encourage development of bioinformatics at research organisations and academic institutions. How this approach will impact on new commercial applications will depend on how well industry and R&D organisations work together. It is hoped that the formation of consortia to develop and direct Biotechnology Regional Innovation Centres (BRIC) will encourage and drive ICT adoption.

The biotechnology sector and the ICT sector need to work closely together to ensure that the information and communication needs of the former are adequately addressed.

3.2.8 Status within the International Context

Whilst ICT diffusion has been more rapid globally than in South Africa for the biotechnology sector, this local emerging sector has adopted the technology either as an early adopter or as an early-late majority adopter. The emerging South African biotechnology sector will not be competitive globally if the development and application of ICT cannot progress here at a similar rate in which it is developing globally.

4. Conclusions and Recommendations

Based on the data presented above, and a number of comments and suggestions that emerged during the interviews and open-ended questions in the survey, the following conclusions and recommendations can be drawn.

4.1 How Can the Biotechnology Sector Better Exploit ICT?

The emerging biotechnology sector could address the identified needs by coordinating their efforts to:

- Ensure that, through the implementation of the National Biotechnology Strategy, the biotechnology sector's ICT and bioinformatics needs are effectively addressed.[18]
- Form partnerships with ICT companies to identify new development opportunities such as software for biotechnology applications; communication systems between equipment and sophisticated visualisation systems for molecular modelling.
- Develop a biotechnology portal for South Africa to enable biotechnology information transfer and communication internationally and nationally.
- Work with government to ensure there is a raised level of awareness of the role of biotechnology and ICT in economic development.
- Work with government and the ICT sector to ensure more integration and development of novel applications.
- Include ICT in current training courses that will lead to new qualifications covering both of these areas of expertise.

AfricaBio (the South African Biotechnology Stakeholders Association) is willing to work with the biotechnology sector, government and the ICT sector to facilitate all the proposed interventions.

[18] See the National Bioinformatics Facility Survey *www.sanbi.ac.za/survey* for further information on the needs of the biotechnology research institutes.

4.2 What can the ICT Industry do for the Biotechnology Sector?

The main technical issue raised by respondents to the study is the urgent need to address bandwidth inadequacies in South Africa. The ICT industry is well placed to drive this improvement and also address issues related to the expense of bandwidth, hardware and software and the development of better infrastructure. It is suggested that bandwidth costs need to be reduced by a factor of 10 nationally and by a factor of 30 internationally (as estimated by a respondent) to allow local groups to become competitive. A key component to drive this cost reduction would be the stimulation of more telecommunication service providers in South Africa. (This is of course a key national issue that is well recognised but is not being addressed fast enough.)

Another key factor identified by respondents is the quality of all ICT service providers, consultants, trainers, etc. In general, this industry is not providing a high-quality service to the end-users. A small biotechnology business noted that service providers and consultants do not give the complete service that they describe and often solve one problem but create several others which are left unsolved to the inconvenience of the end-user. If we are to increase the diffusion and usage of ICT especially for the SMME sector in South Africa, service providers will need to address this issue and the ICT industry needs to regulate itself on the quality and efficiency of the service it provides.

The ICT sector needs to work more closely with the biotechnology sector. In developed countries the ICT sector is creating opportunities to work with the biotechnology sector, for example, holding joint conferences, workshops and training sessions. In addition, the ICT sector should be looking for ways to partner new business ventures with the biotechnology sector. Whilst the ICT sector has initiated projects and formed partnerships with government and business to provide students in some areas with access to computing systems, this sector could also play a valuable role in helping the biotechnology sector stimulate the development of bioinformatics at secondary and tertiary education levels.

4.3 What Can Government Do to Facilitate Growth?

The government urgently needs to address bandwidth issues in partnership with the ICT sector. One respondent illustrated that competitiveness is hampered by excessive Internet costs by indicating that it is cheaper to fly return to London and pick up a tape of the human genome sequence than to transfer it here via FTP (transfer of 10Gb over 2 days = R28 000; return trip to London + tape = R7 000). Reducing Telkom's Internet pricing would have an immediate impact on competitiveness and affordability.

Respondents identified that reliable infrastructure and affordable access were needed to ensure ICT diffusion into Africa. Through its role in NEPAD (the New Plan for African Development), government could actively promote the improvement of access and communication into Africa.

Respondents noted that there were no tangible incentives for ICT diffusion in South Africa. Government could develop incentive schemes that would make ICT more accessible to all, such as tax deductions or concessions for ICT hardware and software especially for SMMEs. Many respondents identified the need for more training at all levels. This issue should be addressed through the SETAs[19] for each sector. In addition, government could enter into partnership with the ICT training providers to offer courses that fit the biotechnology sector's needs. Most organisations do not want their employees attending courses during the day (they cannot afford the down time). They want training programmes that are cost effective (subsidised by government), that can be given in-house at night or over weekends.

Some respondents identified the need for more learnerships sponsored by government for post-graduates entering the biotechnology sector. A post-graduate requires two years of training in-house before they become cost effective members of staff. More emphasis should be given to supporting learnership programmes that provide financial assistance and training both within the organisation as well as ICT training opportunities. This will help to ensure a workforce within the biotechnology sector that has well-developed ICT and biotechnology skills.

Special post-graduate projects could be developed, which provide the opportunity for biotechnologists to work with information and communication technologists. These pilot projects would be aimed at developing new applications of ICT in biotechnology, new products and at improving communication between equipment and process. This in turn would stimulate small business development. According to one respondent, the Department of Trade and Industry (DTI) has so far refused to recognise software development as an industry and so will not fund this rapid growth area and the need for industry training. These types of projects could be addressed under the National Biotechnology Strategy, but these need to be driven by governments departments (i.e. DACST, Education and DTI) working together with the biotechnology sector.

The National Biotechnology Strategy identifies the need for national bioinformatics programmes, the establishment of regional information centres and a national biotechnology advisory committee. However, what is lacking in the strategy is an effective way for government to ensure that government departments are aware of each other's programmes and that they combine their efforts to assist the biotechnology sector rather than frustrate the sector by divergent, uncoordinated and only partially effective projects.

A government public awareness campaign for biotechnology has been identified by the strategy, but will not be effective unless personnel across all government departments understand the role biotechnology will play in South Africa; the regulatory systems in place and that government will be investing well over R250 million per year in biotechnology through its various programmes. The application of ICT to the public awareness campaign is essential. It should be noted that without public awareness and understanding of biotechnology leading to public acceptance

[19] The Skills Education and Training Authorities established by the government for various sectors in South Africa

of the technology, there will be little growth in the biotechnology sector in South Africa and this will also stunt the growth of the sector in Africa.

To ensure that biotechnology is more accessible to all, the ICT sector, government and the biotechnology sector need to work together. Opportunities suggested by respondents as ways in which governments could be assisting ICT diffusion include:

- Providing on-line health centres at hospitals (Internet booths that inform patients of health choices);
- Rural Internet user sites dedicated to health information and biotechnology;
- Free e-learning opportunities;
- Information distribution on ICT benefits to business;
- An ICT database and help-line desk and
- Free Internet access terminals at high schools and libraries.

Remembering that biotechnology is still only an emerging sector, it will rely on mature government and maturing sectors, like ICT, to take lead roles in initiating collaborative projects. Stakeholders in the biotechnology sector would like to participate in these activities and AfricaBio is keen to help co-ordinate improved ICT diffusion into the biotechnology sector.

One of the main messages from the respondents is that there is not much confidence within the biotechnology sector that the government will do anything with the information obtained through this survey process. Whilst the National Biotechnology Strategy is seen to offer research organisations and academic institutes new opportunities (especially to commercialise new products and processes), existing businesses do not see how they will benefit from government interventions. It is crucial that government acts on the information supplied in this report and widely circulates the full survey results to help build credibility within this sector.

5. Appendix: Biotechnology Questionnaire

SURVEY - 2002

PENETRATION OF INFORMATION AND COMMUNICATIONS TECHNOLOGIES (ICTs) INTO EIGHT SOUTH AFRICAN INDUSTRY SECTORS – BIOTECHNOLOGY SECTOR

the dti
THE DEPARTMENT OF TRADE AND INDUSTRY SOUTH AFRICA

This survey is being carried out on behalf of the South African Department of Trade and Industry by Miller Esselaar and Associates. Eight sectors are under study: automotive manufacturing, biotechnology, clothing manufacturing, cultural tourism, deciduous fruit, health, multimedia, and platinum mining. The objective is to help South African stakeholders understand the types of Information and communication technologies and applications used in these economic sectors, the extent to which they are used and their potential for future use. This will help government facilitate their further development and use.
The project will generate three types of key strategic outcomes.

- **South African businesses in the selected sectors will have objective information that will guide their decisions to invest in human and physical capital.**
- **South African ICT companies will have a better idea of what potential demand there may be for their products and services in the selected sectors in the near to medium-term future, and will be able to develop suitable strategies to address these demands.**
- **Government will have a better sense of where to direct some of its research and development programmes and industrial development facilities and more information regarding the commitment of funds for human resource development. Other beneficiaries will be the science councils and a range of education and training institutions, private and public.**

Purpose of Survey

To obtain the perceptions and attitudes of actors at various stages of the value chain in each sector regarding the nature and extent of adoption of Information and Communications Technologies.

Confidentiality

Company/organisation specific information and opinions are regarded as confidential to the researchers and project consultants. Only aggregated information will appear in the project report and be provided to the project sponsors (DTI, IDC and the EU).

Definition of ICT

For the purposes of this study ICT (Information and Communications Technologies) is defined as:

"The goods and services that support the electronic display, processing, storage and transmission of information."

Queries regarding the survey

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SECTION 1: Background Information

1.1 Details of the interviewee [attach business card if available] and organisation

Name:		**Position in Organisation:**		
Organisation Name:		**Address:**		
Description of organisation:				
National versus International: Do you operate in (place an X in the appropriate square)	**South Africa only**	**South Africa and Africa**	**International operations as well.**	
Description of Supply Chain: [comment on the provided diagram of your sector's boundaries and sub-sectors]				
No. of employees in your organisation …… … **(If unsure place a X in the appropriate square alongside)**	**Large (>250 employees)**	**Medium (100-249 employees)**	**Small (10-99 employees)**	**Micro (< 10 employees)**
Approx. no. of PCs in your organisation ……				
Telephone: ( )		**Fax: ( )**		
E-mail:		**Web Address**		

1.2 Interviewee's Involvement with ICT

None or very limited (e.g., only occasional use of office applications and e-mail)				**Extensive (e.g., constant sophisticated usage, designs innovative applications)**
1	**2**	**3**	**4**	**5**

SECTION 2: ICT USAGE

This section examines the extent of ICT usage throughout your firm/institution. The combined results for your sector will indicate the extent of penetration of basic technologies in the sector and its subsectors, as well as the range of applications in use. The results will also allow comparisons across the eight chosen sectors and with similar sectors internationally. Note that we are interested in actual usage**, not simply the presence of the technology.**

Please indicate the extent of your firm's use in each case from 0 to 5, as follows:

Not needed/ don't know	No use at all				Fully utilised
0	1	2	3	4	5

Basic Hardware & Communications Technologies (see explanation of terms at end of questionnaire)		
ICT Hardware	**2.1 PCs**	**0 1 2 3 4 5**
	2.2 Servers/mainframes	**0 1 2 3 4 5**
	2.3 CAD/CAM technologies	**0 1 2 3 4 5**
	2.4 Emerging technologies (e.g., sensing devices, geo-spatial technologies, robotics)	**0 1 2 3 4 5**
Communications Infrastructure	**2.5 Local Area Networks (LANs)**	**0 1 2 3 4 5**
	2.6 Wide Area Networks (WANs)/ Virtual Private Networks (VPNs)	**0 1 2 3 4 5**
	2.7 Dialup Internet Connectivity	**0 1 2 3 4 5**
	2.8 Leased Line Internet Connectivity	**0 1 2 3 4 5**
	2.9 Wireless Networks for Data Transmission	**0 1 2 3 4 5**
Applications		
Information Acquisition and Communications	**2.10 CD-ROM sources**	**0 1 2 3 4 5**
	2.11 E-mail	**0 1 2 3 4 5**
	2.12 Teleconferencing	**0 1 2 3 4 5**
	2.13 Videoconferencing	**0 1 2 3 4 5**
	2.14 Intranets and Extranets (Company information dissemination, document transfer, e-mail, web access)	**0 1 2 3 4 5**
	2.15 The Internet (e.g., advertising, information searches)	**0 1 2 3 4 5**
Streamlining Business Processes	**2.16 Strategy and Planning Activities (e.g., organisational and strategic planning, knowledge management)**	**0 1 2 3 4 5**
	2.17 Business Support Activities (e.g., finance/accounting, data storage and retrieval, personnel management and payroll activities, training)	**0 1 2 3 4 5**
	2.18 Marketing and sales (e.g.: electronic promotional materials)	**0 1 2 3 4 5**
	2.19 Customer Service (e.g.: database records of customers, telephone call centres, customer relationship management)	**0 1 2 3 4 5**
	2.20 Research, development, design and production (e.g.: CAD/CAM)	**0 1 2 3 4 5**

	2.21 Purchasing/procurement (e.g.: Electronic data interchange)	**0 1 2 3 4 5**
	2.22 Manufacture/process control	**0 1 2 3 4 5**
	2.23 Stock and Inventory Control/ Warehouse Management	**0 1 2 3 4 5**
	2.24 Distribution Planning and Control	**0 1 2 3 4 5**
	2.25 Business Process/Systems Integration (e.g., ERP)	**0 1 2 3 4 5**
Transforming Business processes	**2.26 Providing Information (e.g. on CD-ROMs, via websites)**	**0 1 2 3 4 5**
	2.27 Interactive on-line services (e.g. quoting prices, answering queries, taking orders by e-mail)	**0 1 2 3 4 5**
	2.28 Completion of commercial transactions on-line (business to consumer e-commerce)	**0 1 2 3 4 5**
	2.29 Completion of commercial transactions on-line (business to business e-commerce)	**0 1 2 3 4 5**
	2.30 Teleworking (employers and employees do a significant amount of their work using remote access facilities)	**0 1 2 3 4 5**

Which of the above technologies and application areas do you believe need the most emphasis/growth in your firm?

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Which of the above technologies and application areas do you believe are the major inhibitors to achieving your business/organisational goals?

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Are there any major technology gaps that you can identify? Why do you identify them as gaps?

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SECTION 3: ICT Spending Patterns

Depending on the industry and the stage of development of particular firms within the industry, global data shows that there is a wide range of expenditure on ICT (hardware, software, telecomm facilities, ICT human resource, training, support, etc.) ranging from less than 1% of turnover to more than 20%.

Relative to the norm in your sector globally, would you say *your sector's* ICT expenditure in South Africa is

Much less than the norm	Less than the norm	About the norm	More than the norm	Much more than the norm	Don't know
1	2	3	4	5	0

Relative to the norm in your sector in South Africa, would you say your organisation's ICT expenditure is

Much less than the norm	Less than the norm	About the norm	More than the norm	Much more than the norm	Don't know
1	2	3	4	5	0

Relative to other areas in your own firm/organisation, would you say your budget for ICT is growing

Much more slowly	More slowly	About average	More quickly	Much more quickly	Don't know
1	2	3	4	5	0

SECTION 4: Sources of ICT Information and Training

The diffusion of ICT innovations and the adoption within firms is closely related to awareness of such innovations and their potential as well as employee training. In the following tables please indicate your main sources of information related to ICTs and their use in your sector, and sources of ICT training for your professional and user staff (indicate more than one for each category if necessary).

4.1 ICT-related Information

Assign 1 to 3 as follows:

1 = sources least used or not used at all, 2=sources sometimes used, 3= sources most used.

	Source	
1	**ICT suppliers e.g. vendors of software/hardware**	
2	**Specialised private sector trainers**	
3	**In-house training programmes**	
4	**Newspapers, magazines, journals**	
5	**Experts within the company (incl. parent company)**	
6	**Consultants/service providers**	
7	**Trade and business associations**	
8	**Chambers of Commerce**	
9	**Government training initiatives**	
10	**Internet**	
11	**Universities / Technikons**	
12	**Other (specify)**	

4.2 ICT-related Training

Assign 1 to 3 as follows:

1= sources least used or not used at all, 2=sources sometimes used, 3= sources most used.

	Source	
1	**ICT suppliers e.g. vendors of software/hardware**	
2	**Specialised private sector trainers**	
3	**In-house training programmes**	
4	**Newspapers, magazines, journals**	
5	**Experts within the company (incl. parent company)**	
6	**Consultants/service providers**	

7	**Trade and business associations**	
8	**Chambers of Commerce**	
9	**Government training initiatives**	
10	**Internet**	
11	**Universities / Technikons**	
12	**Other (specify)**	

Are professionals in your sector given specific ICT-related training? Is it sufficient? Please explain.
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Are ICTs used in the provision of training in your sector? e.g. computer-based training, e-learning, simulation programs, virtual reality, etc? Please specify.
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Are you aware of any government initiatives supporting the use of ICTs in your industry? Please specify.
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SECTION 5: ICT Adoption: Drivers and Barriers

There are many internal and external factors that influence a particular organisation's decision to invest in ICTs. One or more aspects of the external and internal environment can be a driver for accelerated investment while similar factors may be a real barrier to adoption. An understanding of the main drivers and barriers in a particular sector and across sectors can provide pointers to beneficial actions at the firm level, sector level and national level.

Please rate the following as regards your organisation's adoption of ICT:

1 = strong negative influence (barrier),
2 = negative influence
3 = no particular influence/ not relevant
4 = positive influence
5 = strong positive influence (driver)

External Economic Factors		
1	**General economic conditions in my sector**	**1 2 3 4 5**
2	**My sector's culture and attitude towards ICT**	**1 2 3 4 5**
3	**Expected increased competition in the short term (next two years)**	**1 2 3 4 5**
4	**Expected increased competition in the medium term (next 5 - 10 years)**	**1 2 3 4 5**
5	**Increased global business opportunities**	**1 2 3 4 5**
6	**Increased influence from multinational firms**	

Supply Chain Factors		
7	**Need for increased organisational efficiency**	**1 2 3 4 5**
8	**Need to respond to customer requirements**	**1 2 3 4 5**
9	**Need to respond to supplier requirements**	**1 2 3 4 5**
10	**Need to respond to government requirements**	**1 2 3 4 5**
11	**Need to respond to national or international regulatory/environmental standards**	**1 2 3 4 5**
12	**Need to improve communications**	**1 2 3 4 5**
13	**Need to reduce paperwork**	**1 2 3 4 5**
Internal Factors		
14	**Attitudes of Senior Management towards ICT**	**1 2 3 4 5**
15	**General attitude of personnel towards ICT**	**1 2 3 4 5**
16	**Level of ICT skills in the workplace**	**1 2 3 4 5**
17	**Availability of ICT professional skills**	**1 2 3 4 5**
18	**Perceived cost of ICTs**	**1 2 3 4 5**
19	**Need for increased computing to do business (R&D and other functions)**	**1 2 3 4 5**

- **Do you have an ICT function in your company e.g. IT Manager, Chief Information Officer, Chief Knowledge Officer? Describe this function. Where does it reside? To whom does the person report? What staff complement is associated with the position?**

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- **How concerned is your organisation about the security of organisational data and information? What mechanisms are in place to protect this corporate asset?**

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- **How concerned is your organisation about the confidentiality of personal data? What measures are in place to protect the privacy of the individual?**

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SECTION 6: Diffusion of ICT into Your Organisation/Sector

Everett Roger's well-established model describes the diffusion (i.e., penetration, extent of adoption) of innovations like ICT. In very general terms, how would you characterise your own organisation and your sector? Please consider your own organisation, compare it with others you know in your sector, and compare your sector with others in the economy in general. If you are not familiar with the sectoral or global situation, omit those columns.

In the particular category below, my organisation (or sector) was

1 Among the first few percent to adopt ICT (an Innovator)

2 Among the next 10-15 % percent to adopt ICT (an Early Adopter)
3 Among the next 30-40% percent to adopt ICT (the Early Majority)
4 Among the next 30-40% percent to adopt an ICT (the Late Majority)
5 Among the last few percent to adopt an ICT innovation (A Laggard).

Note that your firm and your sector may be at different levels in a given category

Extent of Diffusion of ICT			
Category of Application	My Organisation	My Sector in the SA Economy	My Sector in the global Economy
1 Product/service innovation: **Using ICT to develop new products/services or exploit new market niches**	**1 2 3 4 5**	**1 2 3 4 5**	**1 2 3 4 5**
2 Market Innovation: **Applying ICT and especially the Internet to create new channels for marketing and distributing products and services**	**1 2 3 4 5**	**1 2 3 4 5**	**1 2 3 4 5**
3 Administrative Process Management: **Using Intranets and the Internet to improve communications, especially via e-mail and Web access**	**1 2 3 4 5**	**1 2 3 4 5**	**1 2 3 4 5**
4 Relationship Management: **Using Extranets, the Internet and Virtual Private Networks (VPNs) to create closer links with other stakeholders (customers, suppliers, interested parties), especially for EDI-based ordering and invoicing and "just-in-time" production.**	**1 2 3 4 5**	**1 2 3 4 5**	**1 2 3 4 5**
5 Resource Management: **Using the Internet to provide or obtain expertise at a distance, like remote consultation, health diagnostics, distance learning and education.**	**1 2 3 4 5**	**1 2 3 4 5**	**1 2 3 4 5**

What types of projects / incentives / schemes should be initiated immediately to stimulate the use of ICTs in your industry and the sector as a whole and who should lead/participate?

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SECTOR-SPECIFIC QUESTIONS

Biotechnology

How do you rate your knowledge management with respect to:

- Dissemination of biological information from your organisation

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- Using biological information as intellectual capital?

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How would you rate your use of the following technologies?
1=not needed; 2=non-existent; 3=embryonic; 4=established; 5=common

Diagnostics	1 2 3 4 5
Detection systems (Includes biosensors, early warning systems)	1 2 3 4 5
Imaging	1 2 3 4 5
Sequencing	1 2 3 4 5
BioInformation: Data collection	1 2 3 4 5
BioInformation: Data management	1 2 3 4 5
BioInformation: Data manipulation	1 2 3 4 5
BioInformation: Data application	1 2 3 4 5
Molecular modelling	1 2 3 4 5
Virtual experimentation	1 2 3 4 5
Robotics	1 2 3 4 5
Identity preservation systems	1 2 3 4 5
Nanotechnology	1 2 3 4 5
Biometrics	1 2 3 4 5
E-learning	1 2 3 4 5

- What specific services or products from ICT do you require for your biotechnology applications (e.g. communication between equipment, customizing &special maintenance).

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Are you aware of any South African companies that are developing new interests in the biotechnology area? If so, who are they and what products/services are they developing?

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Additional comments:

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LAN (Local Area Network)	**A LAN links computers within a building**
WAN (Wide Area Network)	**A WAN links computers between different sites, typically over a network of leased lines.**
VPN (Virtual Private Network)	**A VPN links computers over a network using private Internet channels.**
EDI (Electronic Data Interchange)	**A set of protocols that enables firms to exchange data in standard formats (e.g., invoices, delivery notes)**
E-mail	**A quick and cost-effective way of sending and receiving messages and electronic files via the Internet**
Intranet	**A service within a company which uses the Internet and World Wide Web standards to distribute and display information**
Extranet	**Refers to those parts of the Intranet that are extended to customers and suppliers – it therefore provides access to only certain parts of the company's Intranet. It may include such elements as the staff contact details, marketing materials, etc.**
Internet	**A collection of computers connected together around the world. Provides access to computers, electronic mail, bulletin boards, databases and discussion groups, all using TCP/IP (Transmission Control Protocol/Internet Protocol)**
CD-ROM	**Compact Disc / Read/only memory. A high-density storage medium on which electronic data are etched and read by a laser beam.**
Portal	**A portal is a personalised secure web environment. It allows an organization to aggregate and share content – information, services, and applications -- with customers, partners, employees and suppliers. A portal can bring together technology, business processes, and business partners, enabling the organization to exchange information inside and outside the firewall. A portal allows an organization to employ a single URL through which users receive customized and even personalised information, as well as vital business applications.**