ABSTRACT

Technology development in South Africa has been characterized by strong technological flows from abroad, and weak linkages between industry and research universities. The development of indigenous technological capability has suffered as a result.

In attempting to address this matter, more attention has recently been devoted to campus-industry research relationships. The focus, however, has centered on relationships at traditional research universities, which are involved predominantly in basic research. Little attention has been given to more practically oriented institutions such as South African technikons.

The purpose of this thesis is to assess the potential of technikons for research and development work and to formulate strategies to promote the development and transfer of electronic based technologies there.

The analysis is based primarily on the results of a questionnaire that was sent to technikons to collect information on factors that might influence technikon-industry research relationships.

The survey results show that because of the nature of research at technikons, and their close ties with industry, technikons have significant potential to develop technology that can be effectively transferred to industry. They also show that external interface organizations used widely by research universities to facilitate technology transfer, are inappropriate in the technikon context. It is found that the research profile of staff at technikons is significantly different from that of staff at research universities. This has implications for promoting research and development work at technikons.

The policy analysis suggests that technology development and technology transfer can be promoted by facilitating interaction with industry, by encouraging multidisciplinary research programs, by enhancing research capabilities of staff and by creating an environment more supportive of R&D activity. Specific recommendations to achieve these policy objectives are presented, and issues relating to policy implementation are discussed.

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CHAPTER ONE: INTRODUCTION

Technology development and technology innovation play a major role in the international competitiveness and economic success of a country. The link between technological progress and economic growth is self evident. Improvements in process technology translate into lower manufacturing costs and better quality products. Improvements in product technology result in superior designs which further enhance the competitiveness of products. On a macroeconomic level such technological improvements can lead to greater demand for the country's products both in domestic and global markets, thereby directly stimulating economic growth.

It is estimated that technological development accounted for 80% of the economic growth in the United States since the Great Depression (Young: 1988). This strong dependence on technological development is true for long-term economic growth as well, according to the famous study of Abromovitz and Solow which focussed on United States' economic growth since the American Civil War (Solow:1957). Japan's road to economic success is also well documented. It was based on a strategy that involved selectively acquiring technologies from abroad, adapting these technologies while building up financial and technical capability, and then successfully developing new technologies. It is therefore not surprising that many developing countries increasingly view technological progress as the key to rapid industrialization and economic growth.

This thesis will explore the role of South African technikons within the broader framework of technology development in South Africa. It will focus on technology development and technology transfer at these institutions with
specific emphasis on electronic based technologies. The purpose of this chapter will be to explain why technology development, particularly in electronics based technology, is important for South Africa at this stage in its history, and to highlight important features of South African technikons which would suggest that they could play a significant role in this area.

1.1 Technology Development: A South African Perspective

In South Africa there is a growing realization that technology will have a vital role to play in future economic development. For too long the country has relied on its abundant mineral resources and a supply of cheap labor to establish a competitive position. Apart from a handful of strategic industries, relatively little attention was given to developing indigenous technological capability. Now, at the dawn of a new political dispensation, there is increasing awareness of the formidable economic challenges that still lay ahead. There is general consensus that problems of widespread poverty and unemployment will have to be addressed by focussing more attention on strategies to promote technological development and economic growth.

1.1.1 Technology Acquisition

An important component of technology strategy relates to the acquisition of technological know-how. Countries are faced with decisions regarding the amount and the nature of technology that should be acquired from abroad, relative to that which should be locally developed.

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1This was the overriding theme at a conference on technology and reconstruction at the University of Cape Town, 3-5 March 1991.
For most developing countries technology transfers from abroad provide an important source of new technology. Foreign technology allows recipient countries to avoid duplicative research and development, and sophisticated technologies may be introduced much earlier than would otherwise have been possible.

However, a dependence on foreign technology may adversely affect the development of indigenous technological capability. It may hamper the development of a cadre of local scientists and engineers. It may also retard the growth of links between research institutions and industry. As a result, the focus of domestic research may be diverted from addressing the needs of the country itself, and may find itself catering for a foreign scientific audience instead. Besides restrictive agreements that may be attached to foreign technology transfer, particularly in the export arena, such technology may also be highly inappropriate for local requirements.

South African industry has become heavily dependent on foreign technology. According to Kaplan (1991, p.145)

South Africa can appropriately be seen as a technology colony, in which there are strong technology flows from foreign sources into the universities, the research institutes and local industry;...and in which (there are) weak technology flows from universities and research institutes to industry. Weak capabilities especially in industry ensure that the impetus for technological change is overwhelmingly derived from abroad.

Until very recently there has also been an absence of a coherent policy directed towards promoting indigenous technological capability.

As Kaplan further points out, this situation has been reinforced by the "academic orientation" of research at research institutes and universities. Researchers have
been primarily concerned with the development of the "frontiers of knowledge as defined abroad". There has been a plethora of international publications, with numbers exceeding those from more industrially developed countries such as Taiwan and Korea. From the standpoint of South African industry this has resulted in "the generation of technical knowledge which, in the local context, is of limited practical significance" (Kaplan:1991, p.144). This dependence on foreign sources of technology is especially pronounced in the electronics industry.

1.1.2 The South African Electronics Industry.

The electronics industry in South Africa has grown at an annual compound rate of 16%, doubling every 4 years to a value of R12.7 billion (approximately $4.5 billion) in 1991 (Electronics Industry Federation:1991, p.15). A large portion of the revenue in this industry has traditionally derived from government contracts, related mainly to the military and the telecommunications industry. Clearly this situation will not prevail and is likely to change significantly in the new political dispensation.

In a recent study by the Electronics Industry Federation, it is shown that of 30 developing and developed countries, South Africa has the worst differential between production an consumption of electronic goods. In dollar terms South Africa ranked twenty-second in the world as a consumer of electronic goods, but it ranked as the ninth largest importer of electronic goods (Electronics Industry Federation:1991, p.6).

The general tendency to neglect indigenous technological capability is also prevalent in the South African electronics industry. In 1984 Research and Development in the electronics industry amounted to 2.9% of the local
electronics production, compared with figure of 13\% in Britain in the same year (Reynders:1991, p.4). By 1989 R&D spending as proportion of turnover had dropped to below 2.2\% with approximately 30\% of this being accounted for by military expenditure (Kaplan:1991, p.147). In addition, of this research expenditure, about 14\% was devoted to basic research, which is relatively high for a semi-industrialized country.

Individual electronics companies show a relatively weak commitment to R&D. According to Kaplan (1991, p.147)

Only 100 companies out of a total of more than 1000 companies operative in electronics undertake any R&D at all. For these 100 companies R&D represents a more respectable 4.7\% of turnover, and they employ about 8\% of their staff in R&D. However, on average this represents an R&D staff of only 13 per firm; in many firms the number will be much smaller and often will not constitute a critical mass.

Moreover, the larger multinational corporations which dominate the domestic electronics industry, tend to conduct very little of their R&D locally, preferring rather to import their designs from abroad.

From what has been said above, we see that the notion that South Africa is a technology colony is particularly true of the electronics industry and there appears to be a definite need for South Africa to adopt strategies to promote indigenous technological development and capability in this area.

This need becomes all the more critical if one recognizes the pivotal role that electronics can play in the economic growth of a country. Electronics technology is so pervasive that practically all economic processes are dependant on its application. It acts as an enabling technology for other sectors of the economy. For instance, much of the modern technologies required to maintain the
competitiveness of the manufacturing sector has a basis in electronics. It is therefore not surprising that a strong correlation exists between economic growth in developing countries and their technological capability in electronics.

A question central to this thesis is whether technikons can assist in promoting this technological capability in South Africa.

1.2 South African Technikons

1.2.1 The Nature Of Technikon Education

South African technikons are academic institutions at the tertiary level which provide advanced technical education. Their basic mission is specified by the Department of National Education as follows: "Technikons must prepare students for a specific profession or career and must be aimed at the practice, promotion and transfer of technology" (NATED 02-150).

The technikon system has evolved along a similar path as the Polytechnic Institutes in Great Britain. At present they offer as a basic qualification Diplomas and Higher Diplomas, but will soon also be in the process of issuing degrees. All engineering programs practice co-operative education and it is a requirement of all basic qualifications that students work in industry for a period of a year before the completion of the program. A degree will involve three years study at the technikon with one year industrial in-service training sandwiched between academic years.

While many technikons do offer qualifications at the Masters level with a research component, research activities generally tend to be limited, compared to the research involvement of universities. Research is relatively new to many
technikons, and a research culture is generally absent.

By far the major focus of technikons has been the education and training of skilled people to satisfy the high level manpower needs of industry. To the extent that technology has been transferred from the technikon, it has been accomplished mainly through transfer of technically competent students to industry. In so doing the Technikon has played an important role in economic development, for even in a country where technology tends to be largely imported, there is a need for people with the necessary expertise to apply that technology effectively, and adapt the technology to local conditions.

However, the redesign of engineering programs at technikons which was completed in 1991, placed much more emphasis on project work and applied research. Since then most technikons have increased their research involvement and devoted more attention to providing infrastructural support for research work and project work.

1.2.2 Potential For Technology Development and Transfer

(i) Technology Development

In a broad sense, technology development refers to "the adaptation, enhancement, design and development of products, processes, systems and services" (Jacobson:1991, p.76). Earlier in this chapter mention was made of the fact that research in South Africa generally tended to be of an academic orientation, with limited practical significance to industry. From this can be inferred that there is a need for the focus of research to shift towards the development end of the R&D spectrum and to become more applications oriented.
Because of the practical bias of technikon programs and the closer links that have traditionally been forged between technikons and industry, technikons would appear to be particularly suited to research work that is more practically oriented and that bears a greater relevance to the needs of industry or the economy in general. Research and project work at technikons is therefore more likely to focus on the development end of the R&D spectrum.

The question to be asked is whether the capability of technikons to develop technology is being exploited effectively? One of the objectives of the thesis will be to address this question, and to determine strategies that would enhance technological development at technikons. Since the study intends to focus on electronics based technologies, an attempt will also be made to identify which areas in this field would be most appropriate for technikon research.

(ii) Technology Transfer

In the broadest sense technology transfer refers to "the process by which technology, knowledge or information developed in one area, one organization or for one purpose is applied and used in another area, in another organization or for another purpose" (U.S.Senate Report:1988, p.3). It was mentioned earlier that technology transfer at technikons is primarily accomplished through the transfer of technically competent students to industry.

However, to the extent that technikons are engaged in practical and applied research projects, it is important to question whether the technology developed at the technikon is being effectively transferred to industry. A further objective of this thesis will be to address this question and to determine strategies that could facilitate the transfer of technology from the technikon to industry.
1.3 Structure of the Thesis

This chapter provided a background to the study of technology development and technology transfer at South African technikons. The discussion above suggests that technikons have the potential to play an important role in technology development and transfer. This matter will be further explored in subsequent chapters of the thesis.

Chapter two reviews the literature which may be relevant to an investigation of technology development and technology transfer at South African technikons.

Chapter three deals with the formulation of two hypotheses based mainly on the literature review and on the authors personal experience with technikons. This chapter also briefly discusses the structure of the mail survey that was used to gather the relevant information from technikons.

Chapter four provides a detailed analysis of the responses to the mail survey.

Chapter five presents the policy analysis. The main findings of survey are summarized, the hypotheses are tested against these findings, and specific policy recommendations put forward.

Chapter six concludes the study with a discussion of issues surrounding the implementation of the policy recommendations, and identifies areas for further research.
CHAPTER 2: REVIEW OF RELEVANT LITERATURE

The previous chapter explored the link between technology and economic growth and raised the question of whether South Africa was making optimal use of the R&D resources available to promote economic growth. It was suggested that less resources should be devoted to "blue sky" research, and that more emphasis should be placed on R&D that addressed the needs of industry and society in a more direct manner.

To move in this direction, it will be necessary for universities and technikons to forge closer links with industry. One of the objectives of this thesis is to make recommendations that would enhance research relationships between technikons and industry. However, before such recommendations can be formulated, it is necessary first to understand the factors which motivate universities and industry to engage in research relationships, and to take cognizance of the possible barriers that may impede such relationships.

The purpose of this chapter is to review the relevant literature on university-industry interaction. Since the literature seldom distinguishes between research universities and technical universities, the general information on the topic will be reviewed and then specifically evaluated in the context of technikons. Finally, the chapter looks at certain factors that may influence efforts to enhance the research capabilities of staff in the type of research and development environment that prevails at a technikon.

2.1 The Benefits of University-Industry Research

Universities and industry enter into research relationships because of the mutual
benefits to be reaped by both parties.

2.1.1 Benefits to the University

On the side of the university, research for industry can often serve as a valuable source of funding, particularly at a time when most institutions are experiencing cutbacks in financial support from the state. Furthermore, there are usually fewer bureaucratic procedures associated with the procurement of funding from industry than from the state. In many instances, partnerships with industry could also increase the possibility of funding from the state, since funds may often only be made available for research projects that represent a joint collaborative effort between universities and industry.  

In many instances universities lack funds to acquire the most sophisticated equipment in use in a particular industry. Research partnerships with industry may provide faculty and/or students with an opportunity to gain access to such equipment and facilities.

Research for industry can have positive spin-offs for academic programs as well. By engaging in such research, student and faculty are increasingly exposed to real world problems and the latest applications of technology. This promotes a general awareness of industry's needs, enabling academic programs to be regularly updated and to become more relevant. In certain specialized fields, quality faculty may be difficult to come by. Research involvement with industry could provide the university with access to people who

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2This is certainly the case in South Africa where the Foundation for Research and Development, the state agency that funds research, regards industry involvement in a research project as an important criterion in considering a proposal for funding.
have the requisite expertise in these specialized areas.

The above reasons all featured prominently in a survey conducted by Peters and Fusfeld to determine why universities enter into research relationships with companies (1983, p.34). Most universities chose to interact with companies in order "to obtain access to industry as a new source of funding" (41% of respondents). The next most important reason was "to provide students with exposure to real-world research problems" (36% of respondents).

2.1.2 Benefits to Industry

University-industry research relationships can be advantageous to industry as well. To remain competitive, companies have to continually improve their products. In attempting to achieve this they find themselves under increasing pressure to employ the latest process and product technology. As Merrifield succinctly puts it (1991)

> It is almost axiomatic that any organization that is not continually developing, acquiring or adapting advanced technology has in effect made a strategic decision not to be in business within five to ten years.

With products becoming increasingly sophisticated and requiring inputs from several advanced technologies, few companies can rely solely on internal R&D to develop new technology. It is both expensive and risky to engage in too many research projects simultaneously, particularly if these projects involve diverse technologies and fall at different ends of the R&D spectrum. In an attempt to spread their R&D risk portfolio, companies increasingly acquire new technology from an external source (Bower:1990, pp.3-8). Research programs at Universities can serve as an important source of new technology. They often
provide a "window to technology" for many companies, especially those in the high-tech business.

Through these research relationships industry may also gain an advantage in recruiting qualified personnel, which is particularly important in areas where talent is rare. Students who work closely with a company on a particular project, become familiar with the operation of that company, and are more likely to accept employment from that company if made an offer.

University-industry interaction can also provide companies with access to equipment and facilities. This is particularly true for small companies with limited resources of their own.

The above reasons were some of those mentioned in a survey conducted by Peters and Fusfeld, to determine why companies entered into relationships with universities (1983, pp.36-37). Most companies mentioned that they interacted with universities "to obtain access to manpower" (75% of the respondents). This was followed by 52% of the respondents who indicated that they interacted with universities "to obtain a window on science and technology."

From the above discussion it might appear that university-industry research gives rise to a "win-win" situation because of the mutual benefits that both parties can derive from such interaction. However, this is not necessarily the case. The potential pitfalls of such relationships are also well documented.

2.2 Negative Features of University-Industry Research

Most criticism of university-industry research has been levelled at the threat to academic freedom that such relationships pose.
Feller (1990, p.342) expresses concern at the extent to which industrial funding influences the focus of research and threatens one of the primary missions of academic research, the unconstrained advancement of knowledge. Academic research questions are likely to be constrained by prospects of commercialization, since questions on technological feasibility are usually superseded by questions relating to the market profitability of a research outcome. Feller predicts that the inevitable consequence will be a slow decline in the scientific quality of faculty research.

According to Fairweather (1988, p.47), academic freedom should also carry with it an obligation to encourage the free flow of information through publication and various other mechanisms. However, with industrially funded research the full disclosure of information cannot always be guaranteed. Companies are interested in maximizing profits from their research investment, which often demands that information remain proprietary.

A further danger of industry funded research is that it tends to divert the attention of faculty from teaching responsibilities, as staff are usually placed under pressure to adhere to deadlines set by industry. In the same sense there is also the danger that students could be overburdened by research demands, to the detriment of their personal academic program.

On the side of industry, there are also concerns about issues regarding proprietary of information, as well as concerns on the cost effectiveness of research conducted at university. In the survey cited above, Peters and Fusfeld noted that "a source of innovation" was far down on the list of motivations for businesses interacting with industry. This seems to suggest that industry does not expect campus research to result in marketable products in the short term.
Feller further questions the revenue generating potential of university commercialization activity (1990, pp.339-340). Often the associated increase in costs are overlooked. The need to defend and file patents, to negotiate licenses and to raise venture capital invariably entails additional infrastructure. Industrial liaison offices are often set up to facilitate links with industry. According to Feller, when the full costs of operating these programs are considered, they often fall short of the income that these programs generate. He cites the example of the Wisconsin Alumni Research Foundation (WARF), which according to him, is the "acknowledged pioneer among universities in the creation of an organizational vehicle to capture revenue from faculty invention". By 1985 the WARF had distributed over $150 million in research grants and capital facilities to the University of Wisconsin and received 2,246 invention disclosures. These produced 203 licensed patents (representing 95 inventions), of which 100 (representing 75 inventions) produced income greater than expenses. The total net income from patents was just more than $30 million, with 10 patents producing 90% of that income. This illustrates the extreme low probability of faculty research leading to income generating outcomes. According to Feller (1990, p.346)

Seeking to garner sizeable net revenue streams from increased patent and technology licensing is for most institutions the equivalent of purchasing lottery tickets whose expected value is likely to be less than the purchase price.

Feller's analysis suggests that apart from the major research universities, few other institutions are likely to profit from commercialization activity. For most, such activity may represent a net drain on resources.

The negative aspects discussed above usually translate into barriers that impede university-industry interaction. In formulating strategies to facilitate
university-industry relationships it is necessary that such barriers be carefully understood.

2.3 Barriers to University-Industry Research

The barriers to university-industry relationships may be broadly classified into two categories: cultural barriers and institutional barriers.

2.3.1 Cultural Barriers

The cultural barriers derive from fundamental differences in the basic missions of the university and industry. A university's function is to generate knowledge and to freely disseminate this knowledge to society at large in the form of publications and conference papers. Academics tend to have a much broader time horizon and are generally more interested in exploring new ideas and pursuing interesting questions that take them off into unplanned directions, than completing a project within a specific time frame. Invariably they have other important demands such as teaching competing for their limited time.

On the other hand, the basic mission of industry is to generate profits. To this end it demands a culture where research results can remain proprietary in order to protect competitive advantage. Managers in industry work under totally different time frames. They are results oriented and are under constant pressure to meet deadlines.

These fundamental differences in culture can give rise to conflict, and can inhibit efficient collaboration between university and industry.
2.3.2 Institutional Barriers

Differing institutional norms may also introduce barriers to cooperation. The organizational structure in industry is typically hierarchical and top-down. A university, on the other hand, tends to appear from the outside as monolithic, but is in fact characterized by decentralized authority, with individual departments and even faculty members enjoying considerable autonomy in some areas, while being bound by bureaucratic procedures in others. It usually requires considerable patience on the part of industry to understand the system operating at a university before a collaborative research program can be set up.

Academic divisions at universities are usually arranged on a strict disciplinary basis, which tends to support focussed research in highly specialized areas. This is likely to create problems for interaction with industry, where the product development activity often crosses disciplinary boundaries. Industrial research may demand a multidisciplinary effort, which universities may have difficulty delivering.

It may also be difficult for universities to engage in product development work, since the later stages of development and design work leading to innovation normally need to be conducted in close collaboration with production and marketing staff, which may create logistical problems for universities.

2.4 Technology Transfer Mechanisms

The barriers mentioned above may seriously impede the interaction between universities and industry. In an attempt to overcome these barriers universities have developed a number of mechanisms to promote research relationships and facilitate the transfer of technology from university to industry. These
mechanisms are well documented in the literature and are widely used by institutions of higher education. According to Van Dierdonck (1990, p.551) a National Science Foundation survey was able to identify 464 such technology transfer mechanisms operating at universities in the United States. Among the most commonly used are

(i) *industrial liaison programs*: programs providing companies with access to professors and research through meetings, seminars, symposia and reports on current research

(ii) *technology licensing offices*: these offices facilitate the licensing of technology and promote the transfer of technology to industry.

(iii) *research-oriented industrial parks*: parks which attempt to facilitate university-industry interaction by attracting R&D oriented companies into close proximity to a university.

(iv) *incubator units*: programs providing low rent space to potential entrepreneurs, and enhancing university-industry interaction through physical proximity and services such as faculty consultation.

(v) *technology extension services*: these provide technical and managerial information and assistance, primarily to small business.

(vi) *applied research institutes*: institutes with large multidisciplinary resources and managerial structures designed to deal with contract research.

(vii) *co-operative research centers*: centers where the university collaborates with participating companies in long-term research work.
These mechanisms are mostly designed to obviate the "red tape" normally associated with university-industry interaction, to facilitate access to academic researchers, or to physically relocate some of the research activity in an attempt to free it from the constraints of the academic setting.

How effective have these mechanisms been? The overall performance of these mechanisms has been difficult to assess due to the large number of contributory factors that could affect the outcome. However, there appears to be broad consensus that while some have enjoyed a limit degree of success, others have resulted in dismal failure. According to Shapiro (1979),

> Policy options that result in the formation or maintenance of centers (bureaus, institutes, and laboratories) for application of academic research, with few exceptions, do not accomplish their purpose and do not generate genuine university-industry interaction. ..... Almost all were organized for the application of academic research to society and industry. However, they almost inevitably develop a life of their own, a permanent staff, a diminishing contact with faculty and students.

Since these centers are not clearly linked to the major academic functions at the university, they tend to isolate themselves and to rely increasingly on their own resources and not those of the academic departments. There is diminishing contact between students and staff, and they subsequently lose their ability to function as a genuine link between the university and industry.

Moreover, these centers may even be opposed by faculty who begin to view them as a competitor for limited resources or as yet another bureaucracy imposing controls on university-industry exchange. Hence, instead of eliminating conflict as originally intended, these centers may in fact be achieving the exact opposite.
2.5 A Framework for Analysis

Stankiewicz (1986, pp.101-107) distinguishes three schools of thought on matters regarding interface organizations between university and industry, each advocating different solutions to the problems discussed above:

(i) **internalist solution**: this approach rejects the concept of specialized interface organizations and instead advocates an increase in industrially relevant R&D undertaken within disciplinary departments themselves. The focus of policy measures should be towards eliminating barriers to university-industry interaction in the department. The problem with this approach is the unsuitability of disciplinary departments to cope with multidisciplinary research. Stankiewicz also argues that excessive direct involvement of departments in industrial research, will divert attention from the long term research goals of the academic department and threaten its coherence and integrity.

(ii) **externalist solution**: this approach advocates specialized interface organizations, but insists that these be kept separate from the academic departments. The drawbacks of this approach have already been outlined above and arise from the fact that these organizations tend to become independent units, increasingly isolated from the academic departments. Stankiewicz further argues that this arrangement can inhibit the innovation process which requires easy, direct communication among scientists and engineers from different disciplinary backgrounds who are usually located within the various academic departments.

(iii) **integrationist solution**: this approach advocates that the generation and transfer of technology should be viewed as major functions of a university on par with teaching and research and should be integrated into the mainstream
academic life. Stankiewicz, a proponent of this approach, argues that academic departments should be supplemented by multidisciplinary, technology oriented units or research programs, which would undertake research normally not suitable for disciplinary departments. These units would also interface directly with industry. To achieve proper integration, various disciplinary departments should be adequately represented in the leadership and management of these units and should be actively encouraged to become involved in these multidisciplinary units.

2.6 The Technikon Context

2.6.1 Technikon-Industry Interaction

Three possible approaches to dealing with the problems associated with university-industry interaction are described above. A question which this thesis will hope to address is the appropriateness of any of these solutions to promoting interaction between industry and technikons.

As mentioned before, the discussion in this chapter refers to universities in general, and certain sections may relate more to the situation at research universities. To what extent is this discussion relevant to technikons?

Unlike research universities the mission of the technikon is not to generate knowledge, but rather to prepare students for a career in technology, primarily in industry. The research at technikons is intended to have a practical bias and to focus primarily on the needs of industry.

The literature suggests that the primary motivation for universities engaging in research relationships with industry is to secure additional funding. This may not
be the case for technikons. Interaction with industry may be more important for the purpose of exposing students and faculty to "real world" problems, a vital factor in preparing students for a career in industry.

Much of the literature places emphasis on cultural barriers that impede interaction between universities and industry. This may not be a major factor for technikons, since much of the faculty originate from industry and are therefore likely to have a better appreciation for the culture that prevails there.

On the other hand the institutional barriers may be more significant than at research universities, based on the fact that research work is relatively new to most technikons and that mechanisms to promote research work for industry may not be well developed. Since the primary activity at most technikons remains the instruction of students, faculty may find the demands of teaching to be a major inhibiting factor.

2.6.2 Technikon Research Staff

Faculty involvement in the R&D process is crucial to the success of project work undertaken for industry. To remain active in R&D, faculty must continually upgrade their research skills and keep abreast of current developments in technologies relevant to their particular field. How this process may best be enhanced will depend largely on whether staff more closely resemble the "research scientist" of a research university, or the "engineering technologist" associated with R&D in industry. Since this thesis is also concerned with strategies to promote technology development at technikons, attention should be focussed on approaches to enhance research capabilities of staff as well as their capacity for innovation.
In an insightful article Allen (1988) discusses how important it is in managing innovation in R&D laboratories, to distinguish between the "scientist" and the "engineer". He argues that failure to recognize the distinction between the two can lead to misdirected policy in promoting R&D.

At the root of this distinction lies the differences in the level of education between the two. Engineers are generally educated to baccalaureate level, with some proceeding to a masters level degree. On the other hand, scientists almost always have doctorate degrees. Doctorate research involves a long and complex process of academic socialization, which is not part of the education experience of most engineers. It is not surprising therefore that engineers and scientists will differ considerably in their attitude towards research, and their general approach to work.

Scientists place considerable emphasis on publication which serves to document the end product of their research, and establish priority of their findings. They keep close contact with associates in the field through visits, seminars and informal written exchanges, in what has been referred to as "the invisible college". This invisible college is based on strong scientific norms, most notably the freedom of scientists to select their problem areas for research, and an obligation on scientists to communicate their research findings to the entire research community.

On the other hand, Allen's studies show that technologists do not place much emphasis on publication. Their research output is usually in the form of physical hardware, either a product or a process. They rely on the written word to a lesser extent than scientists do, since much of the relevant information regarding their research is physically encoded in the hardware. They do not communicate as easily or as regularly with colleagues outside of the
organization as do scientists. In industry their choice of problem is severely constrained by the research priorities of the company, and they are usually also prevented from disclosure of results.

In their studies of communication networks in R&D organizations, Katz et al (1981,1983) and Tushman (1979) also show that the engineering technologist has difficulty communicating effectively with extra-organizational information sources. Yet such communication is essential for the innovation process since it is unlikely that all information required for a project will be contained solely within the organization itself. Katz and Tushman's findings indicate that in these circumstances technological gatekeepers have an important role to play. Gatekeepers are key people in an organization on whom others rely for technical information. Their readership of professional literature is significantly greater than the average technologist, and they tend to maintain broader ranging relationships with technologists outside the organization. They mediate between their colleagues and the outside world, gathering relevant information and translating it into a form that is meaningful to their colleagues. They also serve to facilitate the external communication of colleagues. Katz and Tushman's studies further suggest that there are ways to promote the effectiveness of technological gatekeepers in such organizations in order to enhance research and innovation.

In the light of these findings, the question to be addressed is whether faculty at a technikon resemble the "scientist" or the "engineering technologist" as portrayed in the discussion above, since this will have implications for the management of research and development within the school. If it can be shown that faculty are closer to being categorized as technologists, then efforts to promote research and enhance the innovation process in the school will focus squarely on ways to facilitate the role of technological gatekeepers.
The purpose of this chapter was to review the relevant literature on university-industry relationships, to provide a framework for analyzing these relationships and to evaluate the information on the topic in the context of South African technikons. The discussion also focussed on the role of technological gatekeepers in R&D organizations dominated by engineering technologists. This review forms the basis of the following chapter which will deal with the formulation of hypotheses and the structure of the mail survey designed to test these hypotheses and gather further information relevant to this study.
CHAPTER 3: HYPOTHESES AND MAIL SURVEY

With the growing realization that knowledge based resources can play a key role in economic development, attention has been focussed on the optimal use of such resources at research institutes and universities. In this regard the interaction between these institutions and industry has increasingly come under the spotlight.

However, the literature on this topic has tended to concentrate mainly on developments at research universities. The peculiar situation at technical institutions such as South African technikons has virtually been ignored. Yet, as was previously pointed out, technikons are currently engaged in research and development work of their own. It would therefore appear that any strategy to promote the optimal use of knowledge based resources in South Africa should also be concerned with technology development and technology transfer at technikons as well.

It is highly likely that strategies to promote technology development and technology transfer at institutions such as technikons will differ from those being implemented at research universities because of the distinct differences between these types of institutions. In the past the primary role of technikons has been the development of high level technical manpower to satisfy the needs of industry. To this end it has developed closer links with industry than research universities. Research at the technikon tends to have a more practical bias and tends to be directed more towards the needs of industry. Staff at the technikon are also drawn largely from the ranks of industry.
3.1 Formulation of Hypotheses

What would be the appropriate strategies or the appropriate technikon-industry interface for promoting technology development and technology transfer at technikons? This will depend amongst other things on our understanding of the following:

(i) the nature of research and development work at technikons.

(ii) the prior experience of staff in research and development work.

(iii) the primary motivation for technikons to establish research relationships with industry.

(iv) the potential barriers that may impede such relationships

(iii) the experience of technikons with the various technology transfer mechanisms discussed in the previous chapter.

Based on the literature review of the previous chapter, and personal experience of working with technikons, the following hypotheses are put forward with respect to the above:

Hypothesis 1: The university-industry interface mechanisms proposed under the "externalist solution" to university-industry interaction in chapter two, are unlikely to serve as an appropriate vehicle for promoting the transfer of technology from technikon to industry.
This hypothesis is based on the fact that technology transfer at the technikon is accomplished mainly through the transfer of technically competent students to industry. While increasingly more attention is being given to research and development work at technikons, it is still a relatively recent phenomenon compared to the research being conducted at research universities. It is therefore unlikely that technikons would have as yet developed special industry interface mechanisms or related infrastructure to promote the transfer of research results to industry.

At the same time, links between the technikon and industry are likely to be relatively strong, due to the nature of the programs on offer at technikons, suggesting that such mechanisms may have a limited role to play.

A major goal of technikon education is to prepare students for a career in industry. To the extent that external interface mechanisms isolate research activities from academic departments, they would tend to obstruct this goal. This suggests that external interface mechanisms might also be inappropriate at technikons.

_Hypothesis 2:_ Staff in engineering schools at technikons are more likely to be categorized as "engineering technologists" rather than as "research scientists", in the context of the discussion of these concepts in chapter two. As a consequence, strategies to promote R&D at technikons are likely to differ from those that would be more appropriate for research universities.

This hypothesis derives from the fact that very few technikon staff have doctorate qualifications. In 1991 only 2.3% of all technikon educators in the country had qualifications higher than master's level (TESA,1992). However,
many technikon staff have extensive industrial experience, and it is likely that their research experience would have been acquired mainly in an industrial setting. Because of the practical nature of the course work at technikons, it is also likely that the type of research undertaken there would be closer to the development end of the R&D spectrum. This is different from the research environment that prevails at a research university. Therefore in the context of the discussion in chapter two, it is likely that the appropriate strategies to promote R&D would also be different at a technikon.

A mail survey was used to gather information on research and development work at South African technikons. It is hoped that this information could be used to test the above hypotheses and to formulate strategies to promote technology development and technology transfer at technikons.

3.2 The Mail Survey

Since this study concerns electronics based technology, these surveys were sent to the Directors of the Electrical/Electronic Engineering Schools at the various technikons in the country\(^3\). The Director is the academic head of a technikon school, and as such should be in the best position to provide the information sought by the questionnaire.

A copy of the mail survey is provided in Appendix 1. The survey comprised twenty-seven separate questions broken up into six different categories as follows:

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\(^3\)The survey was sent to eleven of the 14 technikons in the country. Of the three excluded one offered correspondence courses only and had no engineering departments. The remaining two were established very recently and lacked experience in the area under investigation.
3.2.1 Research, Development and Project Work

The first nine questions were intended to assess the extent to which the various schools are engaged in research, development and project work and to categorize the type of research being undertaken there. Respondents were asked to indicate their involvement in R&D work during the past two years under each of the following headings: basic research, applied research, development and technical service. The definition of each of these categories, as provided by Tushman and Katz (1980, p.1076), was also included in the survey.4

Since individual projects may vary significantly in size, the number of projects a school undertakes may not by itself provide a good indication of the school's involvement in research work. Respondents were therefore also asked to estimate the money value of those projects sponsored by industry.

The next set of questions in this category explored the nature of the project work in the school. Respondents were asked whether the project work tended to focus on any particular area in the electronics field. It was hoped that the responses would help identify a specific area within the broad electronics field

4Tushman and Katz identify four "task categories" for R&D management as follows:

1. Basic Research: Work of a general nature intended to apply to a broad range of applications or to the development of new knowledge about an area.

2. Applied Research: Work involving basic knowledge for the solution of a particular problem. The creation and evaluation of new concepts or components but not development for operational use.

3. Development: The combination of existing feasible concepts, perhaps with new knowledge, to provide a distinctly new product or process. The application of known facts and theory to solve a particular problem through exploratory study, design and testing of new components or systems.

4. Technical Service: Cost/performance improvement to existing products, processes or systems. Recombination, modification and testing of systems using existing knowledge.
that would perhaps be best suited for project work at technikons. An attempt was also made to gauge the extent to which projects involved the use of multidisciplinary teams of students and/or faculty.

The final set of questions in this category was related to the source of project work in the school. Respondents are asked to indicate the number of projects that originated from contact with industry, the community or that was generated by the technikon itself. An attempt is also made to determine whether the technikon provides any incentives or support for staff who wish to engage in project work or research work.

3.2.2 Consultancy

The next four questions explore the role of consultancy work in the school. The importance of consultancy in university-industry interaction is widely emphasized in the literature on this topic. According to Stankiewicz (1986, p.45), consultancy by university faculty often constitutes the first step towards more advanced forms of university-industry relationships, since it provides a very effective two-way communication channel between industry and the university.

These questions aim to determine the extent to which staff were engaged in consultancy work over the past two years. Respondents were also asked whether staff consultancy work ever gave rise to research or project work in the school. The official policy document governing consultancy work at the technikon was requested. Finally, respondents were asked to indicate on a 1 to 7 rating scale how favorably the technikon viewed staff consultancy work.

The objective of this set of questions was to determine any correlation between the institution’s support for consultancy work and the school’s involvement in
3.2.3 Technology Transfer

A set of four questions in this section was aimed at providing insight into the role of technology transfer in the school and the factors that might influence the technology transfer process. Respondents were asked to indicate the number of instances in which technology developed at the technikon had been successfully transferred to industry, and to describe the factors that they felt might have contributed to the successful transfer of technology.

Respondents were presented with a list of mechanisms and techniques that are widely implemented to promote technology transfer and were asked to indicate on a 1 to 7 rating scale the extent to which each of these were used by the school. Finally, information was requested on the policy governing patenting and licensing at the technikon.

3.2.4 Industry-Technikon Links

This category consisted of a set of four questions aimed at establishing the factors that may have a major bearing on the relationship between the technikon and industry. Two questions dealt with the perceived barriers to interaction with industry. The first focussed mainly on the "institutional barriers" that may inhibit staff involvement in project work for industry while the next question dealt predominantly with the "cultural barriers" as discussed in the previous chapter. In each instance respondents are presented with a list of factors and were requested to indicate the significance of these factors on a 1 to 7 rating scale.

The next two questions explored the major benefits of interaction with industry
and the factors which may have assisted schools in acquiring project work or contract research from industry. Once again a 1 to 7 rating scale was used to determine the technikon's response to these matters.

### 3.2.5 Staff

Strategies to promote technology development at an institution such as a technikon will to a certain degree depend on the staff profile as well as the reward systems operating there. Two questions in this category were aimed at determining the prior experience of staff in research and development work, and in particular, whether this experience was obtained at an academic institution or derived mainly from industry.

The next question attempted to provide insights into the reward system operating at the institution. Respondents were presented with a list of tasks and were asked to indicate on a 1 to 7 rating scale the extent to which staff are encouraged to pursue these tasks by the technikon reward system.

At an institution such as a technikon, with its heavy emphasis on technology, it is imperative that staff keep up to date with the latest advances in technology. In the final question in this section, respondents were presented with a list representing possible sources of information on new technology and were asked to indicate on a 1 to 7 rating scale the extent to which they rely on each of these sources to keep abreast of the latest technological developments.

### 3.2.6 Strategic Planning

The final category consists of a single question designed to determine the extent to which issues related to technology development and technology
Transfer are given attention in the strategic planning process in the school. Respondents were asked to indicate on a 1 to 7 rating scale the extent to which the following matters are addressed:

(i) promoting links with industry for the purpose of acquiring research and development projects.
(ii) managing the research and development process in the school.
(iii) improving the capacities and capabilities of staff to undertake R&D work
(iv) promoting entrepreneurship within the school

Finally, respondents were requested to enclose policy documents pertaining to staff consultancy and licensing and patenting as well as details of collaborative research projects or projects that provide good examples of technology transfer.

Respondents were also asked to provide their e-mail addresses or telephone numbers to facilitate any follow-up queries or requests for additional information. Follow up contact was made in at least two instances, to request clarification on responses to the questionnaire.

The purpose of the survey was to gather information relating to technology development and technology transfer at technikons. It is hoped that this information will provide the basis for policy recommendations in this area and will allow the hypotheses discussed earlier in this chapter to be tested. The analysis of the survey results is dealt with in the next chapter.

Interviews were also held with the Departmental Heads of the Electrical Departments at the Worcester Polytechnic Institute and the Rensselaer Polytechnic Institute to discuss the broad topic of university-industry relationships. These discussions covered much of the same ground as the
questionnaire, and any insights gained from the experiences of these two institutions will be mentioned in support of specific policy recommendations.
CHAPTER 4: ANALYSIS OF SURVEY RESULTS

The results of the mail survey are presented and analyzed in this chapter. As mentioned previously, the questionnaire was sent to all 11 technikons in the country that could provide meaningful input to the study. Responses were received from 10 technikons, yielding a return rate of 91%. This should be high enough for the response to be considered generally representative of electrical/electronic engineering schools at South African technikons. Half of the responses were from technikons where the electrical/electronic engineering schools are relatively large (having an academic staff contingent of 23 or more). The other half were representative of technikons with smaller schools (with an academic staff contingent of 12 or less). Responses were moreover received from technikons in all regions of the country. It is therefore anticipated that the survey results will yield many useful insights into the situation at electrical/electronic engineering schools at technikons throughout South Africa.

4.1 Method of Analysis

Because of the relatively small size of the population under investigation, the survey results were not subjected to a statistical analysis. As far as possible results are presented in a manner that will permit inferences to be made on important issues relating to the thesis. Wherever a rating scale is used, a frequency response of specific ratings are presented in tabular form. However, in interpreting these results, we should bear in mind the subjective nature of the responses. It is expected that the absolute values of ratings will vary among respondents even if their circumstances are equivalent. Hence, care should be taken in drawing comparisons between schools that are based purely on these responses.
The frequency response table does however permit a comparison between the various items on the table, since the ratings do indicate the relative importance of the different items to each school. If schools were consistent in their ratings, then the average rating of responses should provide useful insights into the relative importance of each item to all schools generally. Hence, the average rating of responses are also included in the tables.

From the quantitative information provided, an attempt was made to identify and group schools that were most involved, and schools that were least involved in research and project work for industry. Where appropriate, the average ratings for these groups were also included in the table to observe whether any trends could explain the relative success of one group over the other. However, in this instance we are in effect comparing different schools on the basis of their responses to the questions, and as mentioned above the subjective nature of responses may affect the reliability of the comparison especially since the size of the survey population is so small.

4.2 Results and Analysis

In what follows, the results of each section of the survey are presented and analyzed separately.

4.2.1 Research and Development Work

This set of questions explores the nature and scope of research and development work at technikons. Respondents were requested to indicate the number of research projects undertaken in the technologies related to the broad field of electronics over the past two years (1992-1993). Since all students are engaged in project work of varying duration and degree of complexity
throughout their first three years at the technikon (for instance the course, Design Project, is compulsory for all students in their final semester and invariably involves a lengthy project), respondents were specifically asked to exclude projects that formed part of the program requirement for the National Diploma and National Higher Diploma qualification. The projects reported in the survey would therefore largely comprise those that form part of the Masters level thesis (usually six months to a year in duration), or those undertaken by staff and students to address the needs of some outside organization (mainly industry) or the technikon itself.

The results are presented in Table 4.1. In order to preserve the confidentiality of respondents, the eight technikons are labelled A to J.

As we see from the table, all but one of the respondents are involved in project work, though to a varying degree. In almost all instances the majority of project work forms part of a Masters thesis. This provides an indication of the level and the duration of most of the research work undertaken in these schools.

Respondents were asked to classify the project work according to various R&D categories. Since it is acknowledged that projects may span more than one category, respondents were asked to indicate only the category which is most emphasized. It is also acknowledged that the dividing line between categories is difficult to define and that the definitions provided may have been open to different interpretations. However, from the table we can safely conclude that there is hardly any basic research being undertaken in these schools. Although some schools are engaged in applied research, and many schools are active in the technical service domain, the table suggests that the overwhelming majority of the project work falls in the development category.
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<td>8</td>
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<td>TEAMS. (%)</td>
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**TABLE 4.1. R&D Activity at Technikons**
This implies that much of the research in these schools falls at the development end of the R&D spectrum and is directed towards the development of new products and processes specifically for operational use. In this respect it is similar to the research work that is conducted in industry, which suggests that such research may be of general interest to industry.

Respondents were also asked to indicate the extent to which these projects were sponsored by industry. For six of the schools the sponsorship exceeds R100 000, which is fairly substantial relative to annual school budgets. Much of the sponsorship is used to partially offset salaries of technical staff.

We notice that the schools - D, E, F,G and I - which also happen to be the five larger schools (in terms of staff contingent), appear to be the most active in research and project work. This we gauge not only from the number of R&D projects listed (projects may vary considerably in magnitude and complexity) but also from the size of industrial sponsorship.

The survey was also used to investigate the original source of the projects. For four of the schools the majority of projects (70% or more) originated from industry. For the other five most of the projects originated from ideas generated by staff and students at the technikon.

With regard to the extent to which multidisciplinary teams are used to undertake research, the table clearly indicates that only three schools use personnel from other disciplines in their project teams, and then for only about 20% of the projects.

Five of the ten schools indicated that most of their research tends to focus on a particular area of specialization. This was certainly the case amongst the four
of the five smaller schools, where one may presume that because of their size it made sense to pool resources and develop expertise in a specific area. Of the areas of specialization the following were mentioned: process control and instrumentation, computer interfacing, data communications, alternative energy, software development and digital electronics. Most of these areas are directly relevant to industrial processes.

Seven of the schools mentioned that the technikon provides some incentive for staff to become involved in research work or project work. These incentives generally fall into two categories, reduced lecture load and/or a cash remuneration (either a percentage of the profit generated or a cash bonus).

The information gathered in this section allows us to draw the following conclusions:

(i) there is certainly scope for substantial involvement in research work and project work, as demonstrated by certain schools, most notably respondent E, which engaged in 52 research projects over the past two years, practically at the masters level of research.

(ii) much of this research can be categorized as development work, with a large number of projects originating from industry.

(iii) very few of these research efforts involve the use of multidisciplinary teams.

(iv) smaller schools tend to focus their research on particular areas of specialization.
The information also allowed us to identify at least four of the schools (D,F,G,I) as amongst the more successful in acquiring project work from industry. The analysis of subsequent sections of the survey might suggest some of the underlying reasons for this success.

### 4.2.2 Consultancy

The questions in this section examine the role of consultancy work in the school. The table 4.2 provides an indication of staff involvement in consultancy work, and whether staff consultancy gave rise to research work in the school.

<table>
<thead>
<tr>
<th>RESPONDENT</th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
<th>E</th>
<th>F</th>
<th>G</th>
<th>H</th>
<th>I</th>
<th>J</th>
</tr>
</thead>
<tbody>
<tr>
<td>% staff engaged in consultancy work in 1992-1993</td>
<td>40</td>
<td>0</td>
<td>62</td>
<td>20</td>
<td>25</td>
<td>0</td>
<td>7</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Has research work ever resulted from consultancy work?</td>
<td>✓</td>
<td>x</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
</tr>
</tbody>
</table>

From the above table it is evident that in most schools relatively few staff engage in consultancy work. However, in almost all instances where staff consultancy did take place, the consultancy work resulted in two or more research projects for the school. Respondents provided some interesting examples of such cases.

Respondents were asked about the official policy of the institution towards consultancy work. While most indicated that their institutions generally supported
consultancy work, only two schools provided details of an institutional policy on this matter. It is therefore uncertain whether an actual policy has been formulated on this matter at the other technikons.

From the evidence at hand we must conclude that consultancy generally does not figure prominently in these schools, yet the information clearly demonstrates that it can play an important role in securing project work from industry.

4.2.3 Technology Transfer

This set of questions explores the role of technology transfer in the school and tries to identify factors that may influence the process. Respondents were asked to indicate the number of instances where technology developed in the school had been successfully transferred to industry, the community or put into commercial use. The results are presented in the Table 4.3.

Table 4.3: Technology Transfer

<table>
<thead>
<tr>
<th>RESPONDENT</th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
<th>E</th>
<th>F</th>
<th>G</th>
<th>H</th>
<th>I</th>
<th>J</th>
</tr>
</thead>
<tbody>
<tr>
<td>% Project work sponsored by industry.</td>
<td>44</td>
<td>18</td>
<td>0</td>
<td>40</td>
<td>23</td>
<td>86</td>
<td>95</td>
<td>0</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>% of projects successfully transferred</td>
<td>22</td>
<td>18</td>
<td>0</td>
<td>33</td>
<td>77</td>
<td>90</td>
<td>100</td>
<td>0</td>
<td>69</td>
<td>50</td>
</tr>
</tbody>
</table>

The table also presents the project work sponsored by industry as a percentage of the project work undertaken by the school. Invariably such projects arise out of a particular need of industry. It is therefore assumed that technology developed in these instances will be easier to transfer to industry than in the
case where projects originate from within the technikon itself.

The results suggest that schools A, B, D, F, G, I and J have managed to transfer to industry most if not all of the technologies developed as a result of industrially sponsored project work. However, school E appears to have achieved even more, since in its case the percentage of projects successfully transferred far exceeds the percentage sponsored by industry. The results suggest that school E was also able to transfer to industry technologies associated with many of projects originating from within the school itself. In this respect school E can be identified as one of the more successful schools in transferring technology.

Schools were asked to indicate on a 1 to 7 rating scale the extent to which they made use of certain standard mechanisms or techniques to promote the transfer of technology developed within the school. Table 4.4 provides the frequency of responses. The average rating of all respondents is included in the last column for each item. The column with school E's response is denoted by an asterisk. School H was not included in this table since it has not engaged in project work.

The results indicate that the standard mechanisms for promoting technology transfer as suggested by the "externalist" school of thought, are seldom implemented by the various schools. A few schools make moderate use of industrial liaison programs, and school E cited the science park as an important mechanism. (More specifically, four projects were referred to technikon E by firms operating at a science park in the region, as a result of a staff member's involvement with the science park.) However, the overwhelming majority of schools listed "on-site project work" and "industry-technikon cooperative research" as the mechanism they most use. This seems to emphasize the important role of close interaction with industry to enable successful technology
transfer to occur.

Table 4.4: Frequency Response for mechanisms/techniques used to promote technology transfer.

<table>
<thead>
<tr>
<th>Rating</th>
<th>hardly used</th>
<th>used extensively</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Industrial Liaison Programs</td>
<td>1</td>
<td>3*</td>
</tr>
<tr>
<td>Industry-Technikon Co-operative Research</td>
<td>0</td>
<td>2</td>
</tr>
<tr>
<td>Project work conducted 'on site'</td>
<td>0</td>
<td>2</td>
</tr>
<tr>
<td>Technology Centers or Science Parks</td>
<td>7</td>
<td>0</td>
</tr>
<tr>
<td>Industrial Incubators</td>
<td>6</td>
<td>3*</td>
</tr>
<tr>
<td>Arranging staff Sabbaticals in Industry</td>
<td>7*</td>
<td>0</td>
</tr>
<tr>
<td>Using visiting lecturers from</td>
<td>6*</td>
<td>1</td>
</tr>
</tbody>
</table>

In an open ended question schools were also asked to indicate from their own experiences the factor(s) that most contributed to successful transfer of technology. School E mentioned the fact that those projects which originated from within the school itself, and were not sponsored by industry, were nevertheless designed to fulfil a direct need in industry. This could account for the success in transferring to industry technologies developed at the technikon. It should be noted that at school E, 100% of the projects are undertaken by Masters students. This points to the fact that the school must have close links with industry in order to assign students projects that directly address industries
needs.

Responses from the other schools also emphasize close relationships with industry as the key factor in the successful transfer of technology. The following factors were mentioned:

- interaction between students and industry throughout the project
- industrial sponsorship for the project
- seeking to solve problems for industry; close contact with industry
- delivering practical working models of the project
- students developing projects that are useful
- students being supported by their employer, and working on a project that solves problems for the employer.
- industrial sponsorship resulting in students solving specific problems for industry
- projects are financed by industry and are completed with industrial application as the objective

From what has been said above, it is clear that for successful transfer of technologies to industry, project work in schools have to be largely need driven. Even in instances where the project is not sponsored by industry, if it is initiated with a specific need of industry in mind the chances of successful transfer are considerably enhanced. It would appear, therefore, that in the context of the technikon, technology transfer can be promoted if interaction with industry is improved, so that project work can better reflect the needs of industry.

Finally, respondents were asked whether the technikon had a specific policy governing the patenting and licensing of technology. Only three of the larger schools responded in the affirmative (incidently, in a later section of the
questionnaire only two schools indicated that they have patented or licensed technology). Neither enclosed a policy document elaborating on this matter, though one school did indicate that the patent and licensing policy is incorporated in a 200 page research procedure manual. It appears that schools may only address this issue if and when the need arises.

4. Industry and Technikon Links

The first two questions in this section examines the factors that may influence the research relationships between the schools and industry. The first question focusses essentially on the "institutional barriers" to such relationships. As before, a 1 to 7 rating scale is used. Table 4.5 provides the frequency of responses to this question. In the last column the average rating of all respondents is shown. Immediately beneath this the average rating of the five schools- A,B,C,H and I- which appear to be least involved in project work for industry, is presented for the purpose of comparison.

We note that most of the factors on the table appear to be relatively important in inhibiting staff involvement in project work for industry. "Heavy workload of staff" was rated by most schools as the most important, followed by "lack of appropriate incentives for staff". In a way this was to be expected. Research is a relatively recent phenomenon at most technikons and it is unlikely that reward systems would emphasize the role of research. Staff are still engaged predominantly in teaching, and in many schools are expected to teach between 15 and 20 hours per week. A workload such as this leaves little time for project work or research. This could also partially explain the fact that schools appear to have difficulty meeting industry's deadlines.
Table 4.5: Frequency response
for the most important factors inhibiting staff involvement in project work for industry

<table>
<thead>
<tr>
<th>Rating</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>Avg</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lack of appropriate incentives for staff</td>
<td>2</td>
<td>0</td>
<td>0</td>
<td>3</td>
<td>3</td>
<td>1</td>
<td></td>
<td>4.60</td>
</tr>
<tr>
<td>Heavy workload of staff</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>2</td>
<td>5</td>
<td>2</td>
<td></td>
<td>5.50</td>
</tr>
<tr>
<td>Lack of staff interest in research</td>
<td>1</td>
<td>2</td>
<td>1</td>
<td>3</td>
<td>1</td>
<td>2</td>
<td>0</td>
<td>3.70</td>
</tr>
<tr>
<td>Poor understanding of industry's needs</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>1</td>
<td>2</td>
<td>1</td>
<td>0</td>
<td>3.40</td>
</tr>
<tr>
<td>Lack of staff expertise</td>
<td>2</td>
<td>1</td>
<td>3</td>
<td>0</td>
<td>3</td>
<td>1</td>
<td>0</td>
<td>3.40</td>
</tr>
<tr>
<td>Inability to meet industry deadlines</td>
<td>1</td>
<td>2</td>
<td>0</td>
<td>3</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>4.00</td>
</tr>
<tr>
<td>Bureaucratic obstacles</td>
<td>0</td>
<td>2</td>
<td>2</td>
<td>0</td>
<td>5</td>
<td>1</td>
<td>0</td>
<td>3.90</td>
</tr>
<tr>
<td>Lack of ties with industry</td>
<td>1</td>
<td>4</td>
<td>2</td>
<td>0</td>
<td>0</td>
<td>3</td>
<td>0</td>
<td>3.30</td>
</tr>
</tbody>
</table>

"Bureaucratic obstacles" also seem to a problem in many of the schools. Again, one would not expect to find a well developed administrative infrastructure supportive of research at technikons where research work is relatively new.

For many of the respondents "lack of ties with industry" appeared to be the least of the problems encountered, emphasizing the fact that schools generally have solid links with industry.
In this section there is hardly any significant difference between the responses of the sub-group of schools least involved in industrial project work and that of the general sample.

The second question examines the influence of "cultural factors" on staff’s willingness to engage in project work. The results are presented in Table 4.6. As in the previous table, the average rating of the respondents as well as the rating of the schools least involved in project work are provided. Only nine responses are listed as the school that is not engaged in any project work omitted this section.

Table 4.6: Frequency Response for factors that influence the willingness of staff to engage in project work for industry

<table>
<thead>
<tr>
<th>Rating</th>
<th>no influence</th>
<th>very influential</th>
</tr>
</thead>
<tbody>
<tr>
<td>Concerns about constraints on academic freedom</td>
<td>4 4 1 0 0 0 0</td>
<td>1.67 (1.50)</td>
</tr>
<tr>
<td>Concerns about constraints on freedom to publish</td>
<td>3 6 0 0 0 0 0</td>
<td>1.67 (1.25)</td>
</tr>
<tr>
<td>Unwillingness to engage in practically biased research work</td>
<td>4 1 2 0 1 1 0</td>
<td>2.55 (2.00)</td>
</tr>
<tr>
<td>A preference towards academically oriented research</td>
<td>3 2 1 0 0 2 0</td>
<td>2.44 (3.32)</td>
</tr>
<tr>
<td>Potential conflict with teaching mission of the school.</td>
<td>5 2 1 1 0 0 0</td>
<td>1.78 (1.50)</td>
</tr>
</tbody>
</table>
Unwillingness to adjust
to industry's time frame

<table>
<thead>
<tr>
<th></th>
<th>3</th>
<th>2</th>
<th>1</th>
<th>2</th>
<th>0</th>
<th>1</th>
<th>0</th>
<th>2.22</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>(2.25)</td>
</tr>
</tbody>
</table>

From the Table it is clear that the factors mentioned above (corresponding to the "cultural barriers" discussed in chapter 2) have little influence on staff in the schools. This appears to be true generally, as well as for the specific group that are least involved in project work for industry.

Factors that may be problematic for two of the schools according to the responses are "a preference towards academically oriented research" and "unwillingness to engage in practically biased research work". One school also cited lack of interest as a major problem.

The next question explores the major benefits of interaction with companies as perceived by the schools. The responses are presented in Table 4.7. Once again a 1 to 7 rating scale was used. For the purpose of comparison the overall average rating of all schools is presented in the final column, along with the average of the sub-group that appears to be most involved in research relationships with industry (D, E, F, G and I).

All the items listed on the table are regarded as major benefits of interaction with industry. However, by far the most important benefits stem from the fact that such interaction exposes student and staff to real world problems, and increases the relevance of the course work, thereby enriching the course. The least important of the benefits of interaction with industry was cited "as a source of additional funding". However, it is noted that the schools most involved with industrial research tended to rate "funding source" slightly higher than the rest.
Table 4.7: Frequency Response
for major benefits of interaction
with industry.

<table>
<thead>
<tr>
<th>Rating</th>
<th>no benefit</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>Avg</th>
</tr>
</thead>
<tbody>
<tr>
<td>Source of additional funding</td>
<td>2</td>
<td>0</td>
<td>2</td>
<td>1</td>
<td>2</td>
<td>2</td>
<td>1</td>
<td>4.10 (5.00)</td>
</tr>
<tr>
<td>Exposure to real world problems</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>4</td>
<td>5</td>
<td>6.40 (6.40)</td>
</tr>
<tr>
<td>Access to company equipment/facilities</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>2</td>
<td>3</td>
<td>1</td>
<td>4.80 (5.60)</td>
</tr>
<tr>
<td>Enhance employment prospects of students</td>
<td>0</td>
<td>0</td>
<td>2</td>
<td>1</td>
<td>2</td>
<td>1</td>
<td>4</td>
<td>5.40 (5.00)</td>
</tr>
<tr>
<td>Increase the relevance</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>2</td>
<td>5</td>
<td>3</td>
<td>6.10 (6.00)</td>
</tr>
</tbody>
</table>

The final question in this section explores the factors that have assisted the school in acquiring project work or contract research. The results are presented in Table 4.8. The school H did not respond to this question, since it was not engaged in project work. Once again the average of the schools most involved in research are included in the final column, in brackets.

From the table it appears that student co-operative education programs and staff consultancy have assisted a number of schools in acquiring project work and contract research. Others seem to have benefitted from advisory committees and structured visits to industry. Little use is made of alumni associations. The average rating for schools that are more involved in research work for industry is higher for each item than the overall average, suggesting
that they make more use of the mechanisms or techniques that are listed.

Table 4.8: Frequency response for mechanisms/techniques that assisted schools in acquiring project work or contract research.

<table>
<thead>
<tr>
<th>Rating</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>Avg</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alumni/ alumni associations</td>
<td>7</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>2</td>
<td>0</td>
<td>0</td>
<td>1.89 (2.50)</td>
</tr>
<tr>
<td>Student co-operative education programs</td>
<td>3</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>3.55 (4.50)</td>
</tr>
<tr>
<td>Staff consultancy</td>
<td>3</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>3</td>
<td>2</td>
<td>0</td>
<td>3.55 (4.00)</td>
</tr>
<tr>
<td>Advisory committees</td>
<td>2</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>0</td>
<td>3.33 (4.00)</td>
</tr>
<tr>
<td>Structured visits to industry</td>
<td>1</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>3.89 (4.81)</td>
</tr>
<tr>
<td>Outreach programs</td>
<td>3</td>
<td>1</td>
<td>2</td>
<td>2</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>2.78 (3.06)</td>
</tr>
</tbody>
</table>

From the data gathered in this section we can conclude that "cultural factors" do not inhibit staff involvement with industry. Staff appear to be generally willing to engage in research for industry, but the data suggests that their institutional environment could be more supportive. We see also that their primary reason for interacting with industry is to expose students to real world problems and enhance the relevance of the coursework. This may influence the type of work or the type of relationship with industry that schools may wish to enter into. Finally, we see that schools are most assisted in acquiring project work or
research work by programs that promote interaction with industry. For instance, the co-operative education programs that all schools engage in, demand close and structured contact with industry, since students have to be placed in a suitable work environment and monitored on a regular basis. Staff consultancy and structured visits appears to be another important mechanism for promoting closer contact with industry.

5. Staff

The questions in this section are designed to provide information on staff profiles in the various schools that would be of relevance in assessing their role in the R&D process. The first two questions explore the prior experience of staff in research and development, and their research output over the past two years. The results are presented in Table 4.9.

Table 4.9: Staff experience in R&D work and research output of staff.

<table>
<thead>
<tr>
<th>Respondent</th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
<th>E</th>
<th>F</th>
<th>G</th>
<th>H</th>
<th>I</th>
<th>J</th>
</tr>
</thead>
<tbody>
<tr>
<td>% Staff with R&amp;D experience:</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>at an academic institution</td>
<td>9</td>
<td>28</td>
<td>0</td>
<td>8</td>
<td>16</td>
<td>7</td>
<td>14</td>
<td>10</td>
<td>38</td>
<td>16</td>
</tr>
<tr>
<td>in industry</td>
<td>27</td>
<td>43</td>
<td>25</td>
<td>20</td>
<td>13</td>
<td>11</td>
<td>36</td>
<td>10</td>
<td>4</td>
<td>8</td>
</tr>
<tr>
<td>in industry and academia</td>
<td>9</td>
<td>28</td>
<td>0</td>
<td>4</td>
<td>13</td>
<td>7</td>
<td>14</td>
<td>0</td>
<td>4</td>
<td>0</td>
</tr>
<tr>
<td>Research output of staff:</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>papers published</td>
<td>0</td>
<td>2</td>
<td>0</td>
<td>15</td>
<td>10</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>0</td>
</tr>
<tr>
<td>conference papers</td>
<td>1</td>
<td>2</td>
<td>0</td>
<td>20</td>
<td>8</td>
<td>0</td>
<td>2</td>
<td>0</td>
<td>2</td>
<td>0</td>
</tr>
<tr>
<td>patents/licenses</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>2</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>
From the table it is clear that a small number of staff have experience in R&D work, relative to staff at a research university. Many more have research experience in industry than at an academic institution.

Research output of staff in terms of papers published and patents issued is relatively limited.

The next question explores the reward system at the technikon. Table 4.10 presents the results. As before, the average rating of those schools most involved in research work are presented (in brackets) for the sake of comparison.

| Table 4.10: Frequency response for tasks encouraged by the technikon reward system |
|----------------------------------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|
| Rating                           | 1      | 2      | 3      | 4      | 5      | 6      | 7      | Avg    | 1      | 2      | 3      | 4      | 5      | 6      | 7      | Avg    |
| Undertake research work          | 2.80   | (3.20) |
| Engage in consulting arrangements| 2.40   | (3.00) |
| Perform administrative tasks     | 2.40   | (3.20) |
| Concentrate on teaching          | 3.20   | (4.00) |
| Publish research results         | 2.70   | (3.60) |
| Deliver conference papers        | 3.00   | (4.00) |
Engage in outreach programs

<table>
<thead>
<tr>
<th></th>
<th>4</th>
<th>2</th>
<th>2</th>
<th>2</th>
<th>0</th>
<th>0</th>
<th>0</th>
<th>2.20</th>
</tr>
</thead>
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<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>(2.40)</td>
</tr>
</tbody>
</table>

The table suggests a large spread in the responses to this question with little clear indication of which of the tasks are most encouraged. However, what we can conclude is that "research work" and "publication of research results" which tend to be emphasized at most research universities, generally do not receive much attention in a technikon environment.

The final question investigates how staff keep abreast of technology. Table 4.11 presents the results. Once again the average rating of the schools most involved in research work is presented in brackets.

Table 4.11: Frequency response for sources of information staff may use to keep abreast of advances in technology.

<table>
<thead>
<tr>
<th>Source of Information</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>Avg</th>
</tr>
</thead>
<tbody>
<tr>
<td>Technical articles</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>4</td>
<td>2</td>
<td>2</td>
<td>5.30</td>
</tr>
<tr>
<td>Refereed journals</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>5</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>4.30</td>
</tr>
<tr>
<td>Trade magazines</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>2</td>
<td>5</td>
<td>3</td>
<td>0</td>
<td>5.10</td>
</tr>
<tr>
<td>Conferences</td>
<td>0</td>
<td>2</td>
<td>0</td>
<td>2</td>
<td>4</td>
<td>2</td>
<td>0</td>
<td>4.20</td>
</tr>
<tr>
<td>Short courses</td>
<td>1</td>
<td>2</td>
<td>4</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>3.00</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>used extensively</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(5.80)</td>
</tr>
<tr>
<td></td>
<td>(4.40)</td>
</tr>
<tr>
<td></td>
<td>(5.00)</td>
</tr>
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<td>(5.00)</td>
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<tr>
<td></td>
<td>(5.00)</td>
</tr>
<tr>
<td></td>
<td>(3.20)</td>
</tr>
</tbody>
</table>
Advanced studies  0  5  2  0  0  2  1  3.50 (4.00)
Professional associations  3  1  2  1  2  1  0  3.10 (3.60)
Contact with industry  0  1  1  2  3  2  1  4.70 (4.80)
Contact with universities  2  2  3  1  2  0  0  2.90 (3.40)
Contact with technikons  0  2  1  4  2  1  0  3.90 (4.60)
Suppliers of equipment  1  0  4  1  4  0  0  3.70 (4.20)

The table suggests that staff rely most on technical articles and trade magazines to keep abreast of advances in technology. While contact with industry appears to be moderately used as well, it is clear from the table that contact with universities, and for that matter even contact with other technikons, does not play an important role in keeping staff abreast of advances in technology. Some schools indicated that refereed journals and conferences also serve as a useful source of new technological information.

It is also noted that the average rating of the schools most involved in research work for industry, is generally higher than the overall average in almost all instances, suggesting that communication with external sources of information is important for R&D work.

The information gathered in this section suggests that staff have limited experience in research work, and of those that do, much of the research experience was gained in industry. The research output of staff in terms of patents and publications is also relatively small. This is to be expected given the
heavy teaching load of staff and the absence of any special incentives to encourage involvement in research work or the publication of research results. Finally, the results suggest that contact with universities seldom serve as a source of new technological information for these schools.

4.6 Strategic Planning

The purpose of this section is to explore the strategic planning process in the various schools in an attempt to determine the extent to which research and development work is emphasized. Results are presented in table 4.12. Once again the average ratings of the schools most involved in research work are included in brackets.

<table>
<thead>
<tr>
<th>Rating</th>
<th>not emphasized</th>
<th>heavily emphasized</th>
</tr>
</thead>
<tbody>
<tr>
<td>Promoting links with industry to acquire R&amp;D projects</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1 1 2 1 3 2 0 4.00</td>
<td></td>
<td>(4.80)</td>
</tr>
<tr>
<td>Managing the R&amp;D process in the school</td>
<td>0 2 1 2 0 3 2 4.70</td>
<td>(5.40)</td>
</tr>
<tr>
<td>Improving the capacity/ capability of staff to undertake R&amp;D work</td>
<td>0 2 1 1 2 3 1 4.40</td>
<td>(5.40)</td>
</tr>
<tr>
<td>Promoting entrepreneurship within the school</td>
<td>1 3 0 0 4 2 0 3.90</td>
<td>(4.60)</td>
</tr>
</tbody>
</table>

The response indicates that all the R&D related goals are moderately
emphasized by most of the schools, which suggests that research and development work is demanding attention in the future planning within these schools. It is noted also that the average rating for the schools most involved in research work for industry, is higher than the overall average in all instances. This may suggest that these schools are devoting more attention to R&D work.

In this chapter the results of the mail survey were presented and analyzed, providing useful insights into matters relating to research work and project work in the various schools. This will in turn form the basis for the policy analysis and recommendations in the next chapter.
CHAPTER FIVE: POLICY ANALYSIS

Chapter one of this thesis emphasized the need for indigenous technological development in the South African context, especially in the field of electronics. It also argued for research in South Africa to become more applications oriented and to focus more on the needs of industry and society at large. It would appear that technikons can provide an important vehicle for such research, because of the closer links that they have traditionally forged with industry.

The questions to be asked is whether the capability of technikons to develop technology is being effectively exploited, and whether the technology developed at technikons is in turn being effectively transferred to industry.

The purpose of this chapter is to conduct a policy analysis that will address these two questions, along with other related issues. The first step in the analysis will be to interpret the results of the mail survey to determine the current status of technology development and technology transfer at technikons. This will allow the hypotheses formulated in chapter three to be tested. The policy analysis will also provide a framework for specific recommendations that technikons can implement to promote technology development and technology transfer at their institutions.

5.1 Interpretation of Survey Results

The following inferences flow from the analysis of the survey results in chapter four:

(i) Most of the technikons are actively involved in research and project work.
The overwhelming majority of research projects can be categorized as development work. Many of these projects originate from industry, or are directed towards addressing a need of industry. It would therefore be safe to conclude that research work at technikons are generally applications oriented and of direct relevance to industry. It follows that technikons have the potential to develop technology that can be effectively transferred to industry.

(ii) Staff consultancy takes place on a relatively small scale, though at schools where it does occur, it has given rise to project work within the school. While it is generally permitted at most schools, it does not appear to be strongly supported.

(iii) Transfer of technology to industry does not appear to be a major problem because of the nature of research work at technikons and the circumstances that give rise to such work. The research work is usually conducted in close collaboration with industry. Some projects may be conducted "on site", while others may be undertaken by an employee who is sponsored by the firm to engage in research at the Masters level. Almost always the research topic is selected with a specific need of industry in mind and is conducted with some degree of collaboration or input from industry, all of which facilitates the transfer of the technology to industry.

(iv) Existing programs that promote interaction with industry have assisted most schools in the procurement of project work for students and staff. The student cooperative education programs which involve regular and structured contact with industry, appear to have had an important influence in this area. The primary motivation for schools engaging in research work is to expose students to real world problems, thereby rendering the course work more
meaningful. Such research generally increases the awareness of both students and staff to developments in industry, and allows course material to be revised in a way that will increase their relevance. It is clear from the survey that schools do not regard research relationships with industry primarily as a source of additional funding.

(v) Because of the background of most staff which tends to have a strong industrial bias, the cultural differences between industry and academia appear to have little affect on the willingness of staff to engage in research work for industry. Ties with industry also appear to be strong and should facilitate staff involvement in industrial research. Major inhibiting factors result mainly from the institutional environment. The heavy work load of staff, lack of appropriate incentives and bureaucratic obstacles appear to rank among the most prominent.

(vi) In general, staff have had limited experience in research work. Much of this research experience derives from an industrial setting. Research output in terms of published papers and patents is also very limited. It is clear that teaching and instruction remains the most important activity of staff. Little emphasis is placed on research work and the publication of research results in the reward system of most technikons. However, in terms of strategic planning within most schools, the role of research and development work appears to be receiving increasing attention.

(vii) For most staff technical articles and trade magazines serve as the most important source of new technological information. While links with industry also help in this regard, staff generally do not rely on contact with universities, or even with colleagues at other technikons to keep abreast of advances in technology.
5.2 Testing of Hypotheses

In the light of the above observations the hypotheses formulated in chapter three can be effectively evaluated.

Hypothesis 1: The university-industry interface mechanisms proposed under the "externalist solution" to university-industry interaction in chapter two, are unlikely to serve as an appropriate vehicle for promoting the transfer of technology from technikon to industry.

The externalist solution advocates specialized interface organizations such as technology centers, industrial parks, liaison offices and research institutes to facilitate interaction between industry and the academic department. The idea behind these interface organizations is to physically remove the industry related research activity from the academic setting in an attempt to free it from both cultural and institutional constraints discussed in chapter two. It is also argued that academic departments have to be inward looking and limit their exposure to outside influences in order to perform their important role of socializing young research scientists and engineers in the norms of their discipline (Stankiewicz: 1986, p103). It is the academic departments that establish standards within their discipline and determine the strategic direction of research. It is argued that these goals may be adversely influenced by excessive involvement in industry related research, hence the attempt to relocate the industry related research activity to some external interface organization.

However, in the light of the mail survey results it is evident that much of the above justification for the external interface organizations does not hold in the context of a technikon. The very nature of technikon programs, the career orientation and practical bias of course work and the co-operative education
system, ensure that technikons maintain a high level of interaction with industry. As we have already observed, the cultural concerns that may inhibit faculty at research universities from engaging in industry related research do not affect the willingness of technikon faculty to become involved in industrial research. Finally, technikons do not see their role as socializing their research students in the norms of their discipline. Rather, they generally view their role as preparing students, even their research students, for an appropriate career in industry, a goal that would be further enhanced by interaction with industry.

Hence we see that there is no particular advantage or need for technikons to shift their research activity outside of the academic setting. At the same time there is the danger that external interface organizations may evolve into independent units and become increasingly isolated from the academic departments. The prospect that this might occur is even more of a concern in the technikon context, given the fact that interaction with industry is viewed not so much as an additional source of funding, but more for the purpose of exposing students and staff to real world problems. We therefore concur with hypothesis 1 that specialized university-industry interface mechanisms are unlikely to serve as an appropriate vehicle for promoting technology transfer from technikons to industry.

_Hypothesis 2:_ Staff at engineering schools at technikons are more likely to be categorized as "engineering technologists" rather than as "research scientists" in the context of the discussion in chapter two. As a consequence, strategies to promote R&D at technikons are likely to differ from those that would be more appropriate for research universities.

As discussed in chapter two, research scientists place considerable emphasis on publication of research results, and rely largely on these publications and
contact with associates through the "invisible college" to keep abreast of scientific advances in their field. Research scientists usually also undergo a lengthy period of academic socialization through doctoral research.

However, the mail survey reveals that staff in engineering schools at technikons place little emphasis on publication. Incentives to publish hardly feature in the reward system at technikons. Contact with colleagues at universities and other technikons tend to be generally poor, and are seldom relied upon as sources of new technological information. Also, very few staff have engaged in research at the doctoral level. Hence the evidence suggests that staff in engineering schools at technikons are more likely to be categorized as "engineering technologists" rather than "research scientists".

According to Katz et al (1981), communication with external sources tend to be easier in basic research where research topics are generally more universally oriented. However, as we move toward the development end of the R&D spectrum, projects tend to be more locally defined. Experience within the organizational context influence how members approach a project. Language schemes and norms evolve around a project which facilitates communication within an organization and hinders communication with other organizations.

From the mail survey we see that staff in engineering schools at technikons are predominantly engaged in development work. Hence one would expect these projects to be more locally defined. This coupled with the fact that communication with colleagues at universities or other technikons is relatively poor, seems to suggest a role for technological gatekeepers or boundary spanning individuals at technikons, which would not be necessary at research universities.
5.3 Policy Overview

The objective of this thesis is to formulate strategies to promote technology development and technology transfer at technikons.

From the above analysis we see that, because of the nature of technikon programs and the type of research being conducted there, the transfer of technology from technikon to industry does not appear to present a major problem.

According to MacKenzie (1985, p2), the transfer of technology from university to industry depends mainly on two factors:

(i) the extent to which university generated technology is relevant to the needs of industry, and

(ii) the ease with which technology flows to industry, which in turn depends on the quality of links with industry.

The survey results attest to the fact that research at technikons is indeed relevant to industry's needs, and links with industry are generally very well established. We may therefore safely conclude that as long as technikons continue to focus on research that directly addresses the problems of industry, there certainly does not appear to be the need to create external interface organizations to promote technology transfer. These tend to be expensive to set up and run, and carry the risk of isolating the research activity from the academic department.

From the discussion in chapter two it would appear that the "internalist solution"
to university-industry interaction would be most appropriate for technikons. This approach advocates an increase in industrially relevant R&D to be undertaken within the academic department, with the focus on policy measures that would eliminate barriers to university-industry interaction. The problem that traditional research universities experience with this approach is the unsuitability of disciplinary departments to cope with multidisciplinary research. This problem should not be encountered at technikons, because, as mentioned earlier in this chapter, the role of the academic department is distinctly different.

This is not to say that technikons should refrain from any involvement in external interface organizations. Where these have already been set up, whether by a nearby university or government agency, technikons can benefit from interaction in the same way as they would if they collaborated with industry. One technikon appears to have benefitted from its relationship with a science park and indicated that this involvement spawned at least three research projects.

However, the mail survey also reveals that the research experience of staff in the engineering schools is generally limited. This could be a major drawback if involvement in research is one of the objectives of the school. Therefore there does appear to be a need to expand the range of research capabilities of schools and to enhance the capacity of staff to engage in technology development.

The above analysis suggests that in order to promote technology development and technology transfer, the focus of the technikon’s attention should be twofold:

(i) promote interaction with industry that would give rise to research projects that are of an educational value to graduate students, while at the same time
addressing a specific need in industry.

(ii) enhance the capabilities of staff to engage in research, and create conditions within the school that will promote R&D work.

5.4 Specific Policy Recommendations

Specific policy recommendations for promoting technology development and technology transfer are discussed below.

5.4.1. Promote Staff Consultancy:

The establishment of networks of personal relationships between academics and their industrial counterparts can contribute greatly to the success of technology transfer (MacKenzie: 1985, p2). Staff consultancy serves as an important first step in the creation of such relationships between the academic staff and industry.

The mail survey indicated that only four schools have more than 20% of staff engaged in consultancy work. Yet in all four the consultancy work gave rise to research projects. Many academic institutions in the United States permit staff to perform consultancy work for approximately one day per week. At an institution such as MIT, which operates strong industrial liaison programs, staff consulting is actually viewed as part of a faculty members professional obligations (Powers et al: 1988, p198). Therefore, one method of facilitating technology transfer would be for technikons to create a supportive environment for staff consultancy.

Recommendations:
(i) The technikon should formulate a clear policy governing staff consultancy. Such a policy should stipulate the amount of time that each staff member may devote to such activity, as well as rules governing the remuneration that may accrue to staff as a result of such work.

(ii) The school should establish a database of staff expertise that may be made available to firms in the region, to facilitate contact between firms and staff concerning specific problem areas.

(iii) The obvious concern about encouraging consultancy work is that it could divert attention of staff away from their teaching responsibilities, to the detriment of the academic program. Since undergraduate instruction remains the primary function of technikons, an effort should be made to ensure that the work pursued by staff is relevant to the academic program. All consulting by staff should be declared and carefully monitored by the director of the school.

5.4.2. Promote Industrial Liaison:

Extensive prior interaction between the university and industry provides a solid foundation on which to establish longer lasting research relationships (Doyle et al:1985,p.20). Most technikons already have in place infrastructure that can promote further interaction between the school and industry.

Almost all schools make use of advisory committees with strong representation from industry to ensure that standards are maintained and that the program content reflects the needs of industry. The mail survey indicates that in some schools these committees do serve as an important mechanisms for acquiring project work from industry.
All schools engage in cooperative education programs, and most make use of a co-operative education office to assist with the placement of students in industry for in-service training. In the mail survey about half the schools indicated that co-operative education programs assisted in acquiring projects from industry. Both these bodies could be used more effectively to help identify appropriate research problems in industry.

Recommendations:

(i) Members of advisory committees are usually representative of larger companies which are likely to have divisions engaging in R&D activity. They could then assist in establishing contact between academic staff and the R&D divisions in their respective companies.

(ii) The office responsible for co-operative education could use its industrial contacts to help identify appropriate research problems in industry. A database of such problems could be established along with specific contacts in industry with whom schools could negotiate projects for research.

5.4.3 Establish Contact with Alumni.

The mail survey indicates that technikons make little use of alumni to acquire project work from industry. Yet in the context of forging links with industry it would seem rather obvious that former students could serve as a valuable resource for technikons. They have a thorough knowledge of the technikon and the expertise in the school, and represent a ready made network of contacts in industry. They could be effectively used in locating industrial partners for research programs or identifying problems areas in their respective firms that could serve as a basis for research or consultancy activity.
From the interview with the Worcester Polytechnic Institute it emerged that their network of alumni played a major role in soliciting project work for electrical engineering students. Most graduates found employment in local industry, and were generally willing to support the department. In the context of UK universities, alumni in industry have been described as a major "hidden resource" (MacKenzie:1985, p.4). This certainly appears to be the case at South African technikons.

Recommendations:

(i) Schools should establish a database of former students and try to determine their current employment situation (by mail survey or even telephonically). The focus should be mainly on students who may have been working in industry for at least five years, since they may be well placed in their respective companies to identify appropriate research problems for the school.

(ii) Schools may then embark on a program of selectively contacting alumni with the intent of soliciting research projects for the school.

(iii) Schools should also consider establishing alumni associations to make optimal use of the network of former students in industry. At many institutions alumni associations play an important role in raising funds. They could also assist with co-operative education programs by facilitating the placement of students in industry.

5.4.4 Reduce Bureaucratic Procedures

In the mail survey, many technikons cited bureaucratic obstacles as an important factor inhibiting research relationships with industry. Much of the red
tape can be avoided by granting departments autonomy to negotiate research contracts directly with industry. In this way the persons most knowledgeable about technology and the capabilities of the department will be involved in setting up the research project. It is important that both industry and the academic department have realistic expectations about the outcome of the research relationship to avoid disappointment at a later stage. It is also essential that a broad policy framework be established at the institution to guide the negotiation process.

Recommendations:

(i) the institution must formulate a policy on the patenting and licensing of technology developed by staff and students. This policy must clearly spell out the circumstances under which property rights can be maintained by the individual staff member, the technikon or the sponsoring company.

(ii) the policy should also clearly indicate how costs should be accounted for, and how any profits should be distributed amongst the technikon and persons involved with the research project.

(iii) Individual schools should be given autonomy to negotiate research contracts within this broad policy framework.

5.4.5. Provide Incentives for Research

From the mail survey lack of appropriate incentives for staff emerged as a major factor inhibiting staff involvement in research. Such incentives may fall into three different categories: due recognition for research involvement, remuneration for effort, and time off to do research.
(a) Recognition for research involvement:

At research universities promotion within the system is tied to the quality and quantity of publications in academic journals, and the rate of citation of publications. The situation is different at the technikon, where because of the nature of the research work, little emphasis tends to be placed on publication. Other objective measures need to be established to accord recognition to staff for involvement in research work.

Recommendation:

(i) Technikons should develop a set of criteria for evaluating the research contributions of staff, which would be different from the peer review system operating at research universities. Staff could be evaluated on the basis of patents or licenses issued, consultancy reports submitted or technical papers delivered at professional conferences. In other words more recognition could be given to the contribution of staff to developing technology for industry.

(b) Remuneration:

Technikons should allow a certain percentage of the profits that result from research work, to accrue to the faculty engaged in research. One respondent indicated that profits at that technikon were split three ways, 50% to the research staff, 25% to the respective department, and 25% to the technikon. This system seemed to work well since it provided an incentive for both the department and the staff to engage in research work.

Recommendation:
(i) Technikons should formulate a clear policy on the distribution of profits from research work. The largest share of the profits should accrue to the research staff to provide sufficient incentive to engage in research work.

(c) Time-off to Engage in Research:

Heavy workload of staff was cited as the most important factor inhibiting staff involvement in research work. This is understandable, since with a teaching commitment which for most staff exceeds 15 hours per week, it is extremely difficult to find time to engage in meaningful research activity.

State funding at technikons and hence staff allocation to schools is tied to a subsidy formula based predominantly on student numbers. While this formula is very similar to the one that the state applies to research universities, universities are able to generate funds to support research more easily, by taking on large undergraduate classes. Technikons on the other hand need a lower student/staff ratio at undergraduate level, because of the practical bias of their course work. This results in a higher average teaching load per staff at technikons than at universities. In the long run this problem will only be addressed by changes to the subsidy formula, allowing this formula to reflect the distinct character of technikon education.

In the short term however, schools could improve their situation by involving more students in masters level research, since students at this level are weighted more heavily in the subsidy formula. Where appropriate, use should be made of people from industry to present lectures or to supervise research projects. In this way staff could be relieved of some of the workload and be set free to engage in research.
Recommendations:

(i) Through the Committee of Technikon Principals technikons should lobby the appropriate government department to effect changes to the subsidy formula, in order to ensure that this formula better reflects the nature of education at technikons. The subsidy formula should acknowledge the fact that student/staff ratios will generally be lower at technikons, while at the same time recognizing the need for technikons to become involved in research.

(ii) Schools should encourage students to undertake research at the masters level. A special effort should be made to solicit appropriate research projects from industry, particularly from companies which could participate in the external supervision of the project.

(iii) When motivating for external funding of research projects, an amount should be included to cover the cost of a replacement lecturer, so that the staff members concerned could be set free from teaching obligations and devote more time to research.

5.4.6 Promote Multidisciplinary Research Teams

Research and development in industry is often multidisciplinary in nature. Hence research relationships with industry will often demand a research effort that crosses disciplinary boundaries. Because of the more rigidly established disciplinary structure prevailing at research universities, it is often difficult for these universities to accommodate research that involves cooperation across departmental boundaries. This is one of the reasons why research universities set up external interface organizations to deal with industrial research.
As we have argued earlier, external interface organizations are not deemed necessary to facilitate technology transfer at technikons. Nor should these organizations be necessary to promote multidisciplinary research at the technikon, given that disciplinary structures are not as formally established there. To accommodate multidisciplinary research, schools should consider setting up research programs that cross disciplinary boundaries. For example, a research program in computer aided design and manufacture, and also in numerically controlled tooling, would involve staff from electrical, mechanical, computer science and mathematics departments.

Multidisciplinary research teams also have a role to play in producing critical-mass research groups. According to the critical mass hypothesis some minimum group size is needed to carry out R&D efficiently. While this hypothesis may not hold for basic research, where critical mass may be established by numerous small research groups or individuals collaborating through their invisible college, it is almost certainly valid in the case of the technikon where an invisible college is virtually absent. Critical-mass refers not only to the size of groups but also to the range of skills that members bring into the groups. In both instances multidisciplinary teams can be used to build critical-mass research groups.

**Recommendations:**

(i) Government funding agencies should make funding available subject to the condition that various departments cooperate on a research project.

(ii) Schools should try to promote interaction amongst staff across disciplinary boundaries. This could be achieved by circulating information on the research expertise of staff from different departments, and by arranging for staff from these departments to engage in discussions on their current research interests.
5.4.7 Facilitating the Role of the Technological Gatekeeper

Important distinctions between research scientists and engineering technologists were discussed earlier in this thesis. It was shown that marked differences between these two groups of professionals occur in the area of technical communication. While scientists communicate regularly with others about their work through the 'invisible college', technologists do not appear to make as much use of outside contacts. Yet in order for staff to keep abreast of current developments in technology, it is essential that technical information be constantly imported from outside.

In studying the process by which organizations import technical information, Allen discovered that there was usually a small number of key people who performed this task (1981,p394). These he termed technological gatekeepers, who tended to maintain a much wider range of contacts with technologists outside the organization than their colleagues. They perform the important function of gathering outside information and translating it into a form that had meaning for their colleagues. They also assist colleagues in establishing contact with outside persons who are involved in the same area of R&D.

Recommendations:

(i) To promote the role of gatekeepers, the school should facilitate communication between gatekeepers and other staff members. This can be achieved by arranging for gatekeepers to participate in most research projects, inviting gatekeepers to meetings at which research projects are reviewed or physically locating gatekeepers in an area which is easily accessible to most staff. Informally, their role can also be enhanced by encouraging staff to take lunch breaks and coffee breaks at the same time, and ensuring that
gatekeepers are regularly present.

(ii) To promote their role, the school should also facilitate communication between gatekeepers and the external technological environment. This can be achieved by permitting them to attend more conferences and meetings of professional organizations, or to visit more industrial research laboratories, and also to ensure that they regularly receive the important journals and technical magazines in their respective fields.

5.4.8 Develop Centers of Excellence

The success of research relationships with industry depends crucially on the capacity of the various schools to respond to the specific needs of industry. As Fairweather puts it (1988,p86)

> Developing successful university-industry arrangements is a function of capacity and talent as much as will and desire....Without sufficient faculty, students, financial resources, and industrial interest, the effort cannot succeed.

This provides a rationale for focussing on areas of specialization. Given that many of the schools under investigation have limited resources and a relatively small staff contingent engaged in research, it would make sense for these schools to concentrate their resources in a particular area of research, and help build a critical-mass of researchers in that area. It is evident from the mail survey that the smaller engineering schools at technikons are already specializing in a particular area of research.

The above statement also provides the rationale for developing the expertise of staff in this specialist area of research, since the success of university-industry research relationships depends heavily on the talents and capabilities of staff,
and the quality of their research. Schools should endeavor to develop centers of excellence in their areas of specialization. It should be noted that centers of excellence are not created overnight, but take many years to develop and depend crucially on the dedicated efforts of the individual researchers.

The Rensselaer Polytechnic Institute provides a case in point with one of its most successful relationships with industry, in the area of computer graphics. Faculty initially gained expertise in this area by setting up demonstration programs for students to gain hands-on experience in drafting and surveying. Research in this area was then extended to graduate students who were involved in developing programs for undergraduate courses. From this evolved research and consulting relationships with individual companies as these computer graphics techniques found ready application in industry. The area of expertise has now been extended to computer aided design, and the relationship with industry has also evolved to include continuing education programs and a staff-exchange program with industry.

Recommendations:

(i) In most instances areas of specialization should be built around the strengths within the school, particularly the expertise of faculty or any specialist facilities that may exist. However, it could also be built around specific needs of the local community, industry or even strategic technologies identified nationally. National funding agencies can encourage schools to focus on the latter by making funds available for collaborative research specifically in these designated areas.

(ii) Attention should be given to developing staff expertise in these areas of specialization. A structured program should be drawn up for the appropriate staff to engage in advanced studies or attend conferences and short courses in the
areas identified.

(iii) Where appropriate, staff should also engage in co-operative research programs with research universities in their area of specialization. This will serve to strengthen their expertise and deepen their knowledge base in this area.

(iv) In order to broaden their perspective and keep abreast of recent technological developments, schools should endeavor to establish contact with a wide range of firms that are involved in their area of specialization.

5.4.9 Focus on Appropriate Areas for Research

Clearly the focus of research in any particular school will be determined among other things by the strengths of the school or the specific needs in the local community. However, gauging from the responses to the questionnaire it would appear that certain categories of research may be more appropriate than others.

We have seen that the primary reason for schools engaging in research relationships with industry is to expose students to real world problems and not to raise funds. Hence, to the extent that schools do have a range of projects to choose from, these should be selected on the basis of their educational value and not on their potential to generate revenue for the school.

By far the majority of research undertaken by schools is performed by masters students as partial fulfillment of their course requirement. Schools should therefore preferably select research projects of six to twelve month duration (to be performed by an individual or a team of students) which should be at the appropriate level for masters research.
Even though the survey revealed that technikon staff are generally more familiar with the culture that prevails in industry and the different time frame applicable there, it is evident that many schools still have difficulty meeting industry’s deadlines with respect to research projects. This is understandable given the many other demands on faculty members’ time. Where possible, schools should select projects with some slack time, that do not necessarily fall on the critical path of the company. Such projects may not have the revenue generating potential of those that do fall on the company’s critical path, but as mentioned before, this should not be a matter of concern to schools. One school gave an example of a project that had to be downgraded from the company’s critical path because deadlines could not be timeously met. This points to the need for both parties in the research relationship to be fully appreciative at the outset of the time demands that industry related projects may impose.

Industry deadlines may also limit the scope of schools to become directly involved in the product development efforts of companies, since pressures to speed up the introduction of new products to market may make unrealistic demands on staff and/or students in an academic environment.

Nevertheless there appears to be ample scope for schools to engage in appropriate research for industry outside direct involvement in product development. Companies are always looking for cheaper and more cost effective ways of doing things. Judging from the survey responses, much of the research topics involved the application of electronics in technologies relevant to industrial processes. With the rapid diffusion of electronics technology into almost every industrial process, there appears to be tremendous opportunities for electronic engineering schools to engage in work that is directed towards improving the productivity and efficiency of such processes.
Process applications cover a wide range of electronic equipment used in the design, manufacture and handling of products. These include systems for monitoring, displaying and controlling process variables, computer aided design equipment, numerically controlled equipment, as well as local area networks to establish communication links between systems. Hence, even if schools are not engaged in product development itself, there appears to be ample scope for involvement in the development of equipment or systems that are used in the design and manufacture of these products. Such applications cover all areas of electronic engineering, and are applicable to almost all industries, not only the electronics industry.

Where schools cited examples of product development for industry, these usually involved improvements to equipment already being used by the industry. In one example, a school indicated that a company required them to design and develop a device for monitoring explosives. This basically involved the reverse engineering of a product already in use, in order to produce a more cost effective and improved product. In this instance the product development project did not fall on the critical path of the company.

The Worcester Polytechnic Institute indicated that they rely heavily on project work from industry not only for graduate research work but also for the major qualifying project that all undergraduate students have to complete in their final semester. They usually approached industry for what they referred to as "back-burner" projects, which are projects that companies never really have time to address, but which are nevertheless important.

**Recommendations:**

(i) To the extent that schools are able to select from a number of research
projects from industry, they should choose those that will be of greater educational value, and that will be most suitable for masters level research.

(ii) They should guard against unrealistic expectations about meeting industry deadlines, and try as far as possible to select projects that do not fall on the critical paths of companies.

(iii) They should explore ways of assisting industry in becoming more efficient and productive. The focus of research will therefore mainly be directed not at producing radical breakthroughs in technology, but at incremental improvements to existing products and processes.

This chapter provided a policy analysis of the major issues confronting the development and transfer of electronics based technology at technikons. Specific policy recommendations to promote technology development and technology transfer were then discussed. The next chapter concludes the study. It will identify the major players in the policy process and specifically examine issues relating to the implementation of policy. Finally, topics for further research in this area will be identified.
In 1793 Lavoisier appealed to the leaders of the French Revolution to allow the members of his Académie of Science free reign to pursue pure science in whichever direction their research might lead. He saw the role of the scientist as distinct from that of the technologist.

The spirit which guides scientists ... is not the same as that which guides those engaged in the practical arts. The scientist works only in response to his devotion to science and to add to the reputation he enjoys. .... The person working in the practical arts, in contrast, always has a chance of a practical benefit in view (Lavoisier: 1793,p623).

This view, that scientists should not be expected to produce anything of practical value was rejected by the new regime. The leaders of the New Republic saw no use for pure scientists unless they devoted their talents to discoveries which led directly to application. (Keller: 1984,p166). Lavoisier was subsequently executed.

This conflict between Lavoisier and the new regime illustrates an extreme divergence of views on the role of the scientist, and the precise linkage between pure scientific research and technological innovation. Historical evidence suggests that the time frame between basic research and technological innovation is an extremely long one. However, there seems to be a general understanding that pure science can play an important role, even if only "to

5 This is based on the results of two studies, Project HINDSIGHT (1967), which concluded that basic science in the 20 years prior to a major technological advance has made little contribution to the technology, and Project TRACES (1968), which concluded that the underlying science behind innovation is usually much older than 20 years.
environment" in which technological ideas can be effectively exploited (Keller:1984,176).

It is important for any country that an appropriate balance be struck between pure scientific research and research that is directed towards technological innovation. Where precisely this balance should fall will depend on a number of factors, such as the ease of access to advanced technology from abroad, the stage of development and the indigenous technological capability of the country. The point of departure of this thesis is that in South Africa at the moment the balance tends to be unduly biased towards basic research, and that in a country where technological development has a crucial role to play, more emphasis should instead be placed on research that addresses the needs of industry and society in a more direct manner.

The thesis identifies the technikon as an appropriate vehicle for research that could be directed towards technological innovation. The main objective of this thesis is to formulate strategies that would facilitate this role of the technikon. On the basis of the outcome of a mail survey the thesis proposes specific policy recommendations to promote technology development and technology transfer at technikons. These recommendations have certain implications for the major players in the policy process, namely the individual schools, the technikon administration and the funding agencies. The following section explores issues relating to policy implementation by these players.

6.1 Issues Relating to Policy Implementation

6.1.1 Individual Schools

Undergraduate instruction remains the primary goal of technikons. Earlier we
argued that this goal can be enhanced by involvement in research relationships with industry, since such relationships expose faculty and students to real world problems, and thereby help to enrich the academic program. However, schools should also recognize that too much involvement in research will serve to divert the attention of staff from their teaching responsibilities, and thereby adversely affect the academic program. As part of their strategic planning activities schools must therefore firstly decide on the appropriate balance between research activities and instruction activities. This will be determined mainly by the size of the staff contingent and the total commitment to undergraduate instruction.

Since successful research involvement with industry is usually built on a network of personal relationships between staff and industry, schools should implement the policy recommendations in the previous chapter to promote staff consulting and staff contact with alumni. They should also use existing liaison offices and advisory committees to facilitate interaction with industry for the purpose of promoting research relationships. However, it is important that these bodies act only as facilitators. Their role should be to bring prospective research partners together without interfering with the process of technology transfer itself. Since technology involves a large knowledge component, it is best transferred by people who are most familiar with the technology (Van Dierdonk et al: 1990, p563). These would be the actual people engaged in the research.

Effective communication is important to maintain current knowledge of technical advances and to stimulate creativity in a research environment. Schools should implement the policy recommendations to promote technical communication both within the organization and with the outside world. To this extent special attention should be given to the role of technological gatekeepers. However, it is important to note that gatekeeping is an informal role. It is not a role that any
member of staff can simply be instructed to perform. Gatekeepers are people who naturally perform the functions described in the previous chapter. Hence a primary task of the organization is to identify the persons who appear to be most closely fulfilling the role of technological gatekeepers in the organization, and then to adopt the measures listed in previous chapter that would enhance their role.

As far as possible schools should pool resources and try to develop centers of excellence in a particular area of specialization. The area of specialization could be based on the strengths of the school, the needs of industry or the community or the focus of research at neighboring institutions.

It was also mentioned that schools should set up multidisciplinary research programs to accommodate research that involves cooperation across departmental boundaries. These programs could be based in any one of the departments involved in the program but would probably be more appropriately housed in the department where the project-related physical hardware was being developed. While it is true that disciplinary structures are not that rigidly established at technikons, it would be advisable to encourage departmental participation in these programs by ensuring that all the disciplines are adequately represented on the committee managing the program.

Finally, schools should differentiate their role from that of traditional research universities, and try to establish an ethos of their own. In describing the development of technical institutions in Europe, Ferné attributes the initial lack of success of some of these institutions to the fact that their first generation of personnel were attracted mainly from traditional research universities. The model of traditional institutions was largely followed and their values tended to predominate. According to Ferné,
The result has been profoundly disappointing because, not only has the technical ethos failed to emerge but the attempt at copying the traditional institution has not been a notable success either. As a result these new institutions have the worst of both worlds; they attract neither the interest of national research councils nor the support of industry (Fermé et al., 19, p19).

To the extent that they are involved in research, technikons should continue to focus on technical problem-solving support for industry and the local community, and guard against undue involvement in "blue sky" research. They should strive to become first-rate technikons, instead of engaging in basic research and running the risk of being regarded as second-rate research universities.

Besides, there appears to be a demand for the type of R&D work that technikons are most suited to perform. Earlier it was mentioned that electronic firms in South Africa are generally characterized by a weak commitment to R&D. Such firms do not have the internal research capabilities to benefit from basic research, but will be able to take advantage of research that is directed more closely at their specific needs.

6.1.2 Technikon Administration

Industry related research will have to be reflected in the mission of the institution in order to enjoy any measure of success. Academic missions are usually very complex, and support a wide variety of goals ranging from education and research, to community service and involvement in economic development. Ideally the academic institution should try to strike an appropriate balance and devote some attention to all these goals. Given the limited resources at their disposal, however, academic institutions may in fact find this difficult to achieve in practice.

For technikons to pursue research related goals in the South African context will
be particularly difficulty. In South Africa a clear priority in the new political
dispensation will be to provide technical education for the millions who were
denied access to both education and technology in the decades under
apartheid. Technikons and technical colleges will be expected to play an
important role in this regard. It is likely that these institutions will be heavily
committed to technical education, which in turn will limit the extent to which
schools may become involved in research relationships with industry.

Hence, it is important that the institution decide upfront on the extent of its
commitment to economic development through applied research. It will then be
necessary for the leaders and administrators to articulate this vision of the
institution's role, and to demonstrate how involvement in economic development
relates to the mission. Strong, innovative leadership will be required to
successfully balance such involvement with the institutions other obligations.

Technikon leaders and administrators should resist attempts at micro-
management, and allow individual departments sufficient autonomy to negotiate
research relationships with industry. It is important however that a policy
governing staff consultancy, patents and licensing be put in place, in order to
provide the necessary framework for such negotiations. An improved policy
framework may not necessarily lead to improved performance on its own, if
incentives are too weak. Therefore a reward system that recognizes the
contribution of staff to the development and transfer of technology must also be
put in place, as suggested in the previous chapter.

6.1.3 Government Funding Agencies

The government has an important role to play in technology development and
technology transfer. At a general level, the development and diffusion of
advanced technologies require a system of education and training for supplying technology and skills, a legal framework for defining and enforcing property rights, and processes such as standardization to reduce transaction costs and improve efficiency of markets. To the extent that these are public goods they will be largely the responsibility of the government.

More specifically the government can strengthen national technological capabilities by targeting "critical technologies" for government support. These are technologies that may be of strategic importance for national security or for promoting international competitiveness.

In the South African context it will be important firstly to develop indigenous technological capability by focusing on education and training in general, and then to develop capability more specifically in those technologies deemed critical for economic growth. It will also be important to determine the extent to which such technologies should be acquired from abroad, or be supported by basic research, or by research that more directly addresses the needs of industry and the community. These are not easy matters to decide, and will flow directly from the country's overall technology policy. However, once these matters are determined, government funding agencies will have an important role to play in the implementation of this policy.

Earlier in the thesis it was argued that more resources should be devoted to applied research work. Funding agencies can promote research in this area by funding programs that encourage university-industry research and development links. The following schemes can facilitate such links:

(i) Cooperative grants to fund joint research efforts between universities, technikons and industry. The companies involved in this scheme should provide
part of the finances. The amount of sponsorship could determine whether
companies retain licensing rights.

(ii) Grants to fund multidisciplinary research at universities and technikons.

(iii) Industrial Fellowships to enable academic staff to be seconded to industry
to participate in research and development work there.

(iii) Schemes that provide financial support in specific areas of technological
application. An example of this which is pertinent to this thesis is the
Microprocessor Applications Project which was funded by the Department of
Trade and Industry in Britain to encourage manufacturing firms to apply
microelectronics in their products and processes. The project supported
research and development and consultancy work in most areas of
microelectronics and computer application (OECD 1989,p78).

Programs such as these will provide an excellent opportunity for technikons to
engage in research relationships with industry.

6.2 Issues and Suggestions for Further Research

The policy recommendations of the previous chapter are based mainly on the
outcome of a mail survey conducted with technikons in South Africa. Research
relationships between technikons and industry is a relatively recent phenomenon
compared to equivalent institutions abroad, in particular the polytechnic
institutions of Great Britain, on which technikons appear to have been modelled.
Another approach to this research topic would have been to study the evolution
of equivalent technical institutions abroad, to learn from their successes and
failures in developing research relationships with industry, and to identify policy
recommendations that flow from their experiences in this area. However, this approach should be adopted with the necessary caution since often we may find that successful policy implementation in one country could translate into policy failure in another, whenever socio-political, cultural and institutional factors are vastly different.

In exploring research relationships between the technikon and industry, the thesis focussed specifically on the situation that exists at technikons. It tried to determine the positive and negative aspects of such relationships, and the barriers that make it difficult for technikons to enter into such relationships with industry. It may however be instructive to focus on the other partner in this relationship as well. To do this, similar research needs to be conducted on the side of industry. For a more complete understanding of university-industry interaction, it will be necessary to investigate the factors that motivate industry to enter into research relationships with universities, and the factors that inhibit them from doing so. In the South African context, it may also be necessary to investigate the technology acquisition strategies of firms to understand why technology, especially electronics based technology is still largely imported from abroad.

The thesis focussed on technology development and technology transfer that occurs mainly between the technikon and industry. Yet technikons can play an important role in addressing the needs of the general community as well. This is particularly true in a country like South Africa where the majority of the people are living in conditions typically associated with developing nations of the world, conditions characterized by lack of housing, electricity and proper sanitation. Research needs to be undertaken into technologies that would be appropriate for improving the living conditions of the people. Technikons, with their focus on applications oriented research, can provide an ideal vehicle for such research
and development. Hence another area for further research will be the investigation of appropriate technologies for improving the living conditions in developing countries and addressing specific problems of the communities there.

Yet another area that warrants research is the promotion of entrepreneurship amongst students at the technikon. The South African economy, like that of most developing countries, is characterized by a large informal sector. Millions of people are self-employed because of the lack of the formal sector to provide sufficient jobs. The technikon's mission is to prepare students for a technical career mainly in industry, yet despite the projected demand for technological manpower in the country, the reality is that a fair proportion of students will not be able to find appropriate work in industry. Such students should be encouraged to start up their own businesses in areas of technical service, the maintenance and repair of equipment and also in development work. Hence another area for further research could focus on ways to develop entrepreneurial skills and the innovative capacities of students.

6.3 Concluding Remarks

A point of departure of this thesis is that indigenous technological development will have a vital role to play in the future economic growth of South Africa. This is particularly true in the field of electronics, where firms show a weak commitment to R&D, and acquire much of their technology from abroad.

The results of the mail survey suggest that technikons can play an important role in developing indigenous technological capability. Based on the survey results, the thesis recommends strategies that will promote technology development at technikons, and allow technology to be effectively transferred
to industry.

However, the role of technikons must be viewed within the broader context of a country emerging from decades of oppression, during which only a privileged few were granted access to education, particularly technical education. The demand for technikons to cope with the substantial backlog in technical education will effectively limit the extent to which they can engage in research relationships with industry. Under these circumstances successfully balancing research involvement with the technikon's primary responsibility of instruction will be a significant challenge on its own.
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SURVEY ON TECHNOLOGY DEVELOPMENT AND TECHNOLOGY TRANSFER AT TECHNIKONS

November, 1993

Anthony Staak, MIT Technology and Policy Program

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Cambridge MA, 02139
SURVEY ON TECHNOLOGY DEVELOPMENT AND TECHNOLOGY TRANSFER
AT TECHNIKONS

Instructions: Please respond to the questions by circling the appropriate number, checking the appropriate box or writing in a brief answer based upon your own opinion and experience. Your responses will be treated in strict confidence. Do not answer any question you may feel is inappropriate.

1. RESEARCH, DEVELOPMENT AND PROJECT WORK

We need an idea of the nature and scope of research or development work in your school, specifically in technologies related to the broad field of electronics (include control engineering and software engineering).

1.1 Please indicate the number of research or development projects undertaken in the school over the past two years (1992 - 1993)? (exclude projects that form part of the course requirement for the National Diploma or National Higher Diploma qualification).

Number of research or development projects

1.2 Approximately what percentage of these projects could be classified according to each of the following R&D categories? (while projects may span more than one category, consider only the category which is most emphasized)

Basic Research: (work of a general nature intended to apply to a broad range of applications or to the development of new knowledge about an area.)

Applied Research: (work involving basic knowledge for the solution of a particular problem. The creation or evaluation of concepts or components but not development for operational use)

Development: (The combination of existing feasible concepts, perhaps with new knowledge, to provide a new product or process. The application of known facts or theory to solve a particular problem through exploratory study, design and testing of new components or systems)

Technical Service: (Cost/performance improvement to existing products, processes or systems. Recombination, modification and testing of products, processes or systems using existing knowledge)
1.3 Approximately how many of these projects formed part of a Masters level thesis? ______________________

1.4 Approximately how many of these projects were sponsored by

Industry ______________________
Government Agencies ______________________
Technikon ______________________
Other sources (please specify) ______________________?

1.5 What was the approximate rand value of industrial sponsorship of projects over this period? ______________________

1.6 Is there any particular area (an area of specialization) that most of the project work in the school tends to focus on? □ Yes □ No

If yes, please describe ______________________

1.7 Approximately how many of these projects originated from

contact with industry ______________________
contact with the community ______________________
contact with universities ______________________
ideas generated by staff/students ______________________
other sources (please specify) ______________________?

1.8 How many of these projects involved

students/staff working in teams (team projects) ______________________
students/staff from other disciplines (multidisciplinary projects) ______________________?

1.9 Does the Technikon provide any special incentives or any specific support (infrastructural or otherwise) for staff who wish to engage in project work or research work? □ Yes □ No

(if yes, please specify) ________________________________________________

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2. CONSULTANCY

2.1 What is the size of the academic staff contingent in the school? 

2.2 How many were engaged in consultancy work over the past two years? 

2.3 Has research or project work in the school ever resulted from staff consultancy work? □ Yes □ No

(If yes, please give an example) ________________________________

______________________________

2.4 What is the official policy of the institution towards consultancy work? (is there perhaps a policy document on this issue that you could enclose)

______________________________

______________________________

2.5 How would you rate the Technikon's attitude towards staff involvement in consultancy work?

(1=strongly discourages; 7=strongly supports)

1 2 3 4 5 6 7

3. TECHNOLOGY TRANSFER

We would like to understand the role of technology transfer in the school, and the factors that may influence this process.

3.1 In how many projects completed during the past two years, has the technology developed at the technikon been successfully transferred to industry, the community, or for commercial use (i.e. where the technology developed has been implemented or effectively been put into practice)? 

3.2 From your experience in these projects, which factor(s) may have most contributed to the successful transfer of technology?

______________________________

______________________________

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3.3 To what extent are the following mechanisms or techniques used to promote the transfer of technology developed in the school? (to industry, the community or for commercial use):

<table>
<thead>
<tr>
<th>Mechanism</th>
<th>1</th>
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<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
</tr>
</thead>
<tbody>
<tr>
<td>Industrial liaison programs (programs that keep industry informed of R&amp;D being conducted at the Technikon)</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
<td>7</td>
</tr>
<tr>
<td>Industry - Technikon cooperative research</td>
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<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
<td>7</td>
</tr>
<tr>
<td>Project work conducted 'on site'</td>
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<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
<td>7</td>
</tr>
<tr>
<td>Industrial incubators to develop new companies</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
<td>7</td>
</tr>
<tr>
<td>Technology centers or science parks</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
<td>7</td>
</tr>
<tr>
<td>Arranging staff-sabbaticals in industry</td>
<td>1</td>
<td>2</td>
<td>3</td>
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<td>7</td>
</tr>
<tr>
<td>Using visiting lecturers from industry</td>
<td>1</td>
<td>2</td>
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<tr>
<td>Other (please specify)</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
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</tbody>
</table>

3.4 Does the Technikon have a policy governing patenting and licensing of technology?  
☐ Yes  ☐ No

If yes, please provide details. (or preferably enclose the policy document relating to this issue)

4. INDUSTRY / TECHNIKON LINKS

4.1 What have you found to be the most important factors inhibiting staff involvement in project work for industry:

<table>
<thead>
<tr>
<th>Factor</th>
<th>1</th>
<th>2</th>
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<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
</tr>
</thead>
<tbody>
<tr>
<td>lack of appropriate incentives for staff</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
<td>7</td>
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<tr>
<td>heavy workload of staff</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
<td>7</td>
</tr>
<tr>
<td>lack of staff interest in research</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
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<td>6</td>
<td>7</td>
</tr>
</tbody>
</table>

111
<table>
<thead>
<tr>
<th>Poor understanding of industry's needs</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
</tr>
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<tbody>
<tr>
<td>Lack of staff expertise</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
<td>7</td>
</tr>
<tr>
<td>Inability to meet industry deadlines</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
<td>7</td>
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<tr>
<td>Bureaucratic obstacles</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
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<td>7</td>
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<tr>
<td>Lack of ties with industry</td>
<td>1</td>
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<td>6</td>
<td>7</td>
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<tr>
<td>Other (please specify)</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
<td>7</td>
</tr>
</tbody>
</table>

4.2 To what extent do the following factors influence staff's willingness to engage in project work for industry?

<table>
<thead>
<tr>
<th>(1=no influence; 7=very influential)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Concerns about constraints on academic freedom that may result from such work</td>
</tr>
<tr>
<td>Concerns about constraints on the freedom to publish that such work may impose</td>
</tr>
<tr>
<td>Unwillingness to become involved in practically biased research work</td>
</tr>
<tr>
<td>A preference towards academically oriented research</td>
</tr>
<tr>
<td>Potential conflict with the teaching mission of the school</td>
</tr>
<tr>
<td>Unwillingness to adjust to industries' time frame</td>
</tr>
<tr>
<td>Other (please specify)</td>
</tr>
<tr>
<td>Other (please specify)</td>
</tr>
</tbody>
</table>
4.3 What have you found to be the major benefits of interaction with companies?

<table>
<thead>
<tr>
<th>Benefit</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
</tr>
</thead>
<tbody>
<tr>
<td>Source of additional funding</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Exposure to real world problems</td>
<td></td>
<td></td>
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<td></td>
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<tr>
<td>Access to company facilities/equipment</td>
<td></td>
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<td></td>
<td></td>
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<tr>
<td>Enhance employment prospects of students</td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Increase the relevance of, and thereby enriching, the course work</td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Other (please specify)</td>
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<td></td>
</tr>
</tbody>
</table>

4.4 To what extent has the following assisted the school in acquiring project work or contract research?

<table>
<thead>
<tr>
<th>Program</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alumni / Alumni associations</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Student co-op programs</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Staff consultancy</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Advisory committees</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Structured visits to industry</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Outreach programs</td>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Other programs (please specify)</td>
<td></td>
<td></td>
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<td></td>
<td></td>
</tr>
</tbody>
</table>

113
5. STAFF

5.1 How many staff have prior experience in research or development work either

at an academic institution

in industry

or at both of the above

5.2 What was the research output of staff over the past two years in terms of

papers published

conference papers delivered

patents / licenses issued

5.3 To what extent does the technikon reward system encourage staff to

(1=not at all; 7=very much)

undertake research/project work

engage in consulting arrangements

perform administrative tasks

concentrate on teaching

publish research results

deliver conference papers

engage in outreach programs
5.4 Please indicate the extent to which staff rely on each of the following as a means of keeping abreast of advances in technology:

<table>
<thead>
<tr>
<th>Means of Keeping Abreast</th>
<th>1=not at all:</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
</tr>
</thead>
<tbody>
<tr>
<td>technical articles</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
<td>7</td>
</tr>
<tr>
<td>refereed journals</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
<td>7</td>
</tr>
<tr>
<td>trade magazines</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
<td>7</td>
</tr>
<tr>
<td>conferences</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
<td>7</td>
</tr>
<tr>
<td>short courses</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
<td>7</td>
</tr>
<tr>
<td>advanced studies</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
<td>7</td>
</tr>
<tr>
<td>professional associations</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
<td>7</td>
</tr>
<tr>
<td>contact with industry</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
<td>7</td>
</tr>
<tr>
<td>contact with universities</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
<td>7</td>
</tr>
<tr>
<td>contact with technikons</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
<td>7</td>
</tr>
<tr>
<td>suppliers of equipment</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
<td>7</td>
</tr>
<tr>
<td>other (please specify)</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
<td>7</td>
</tr>
</tbody>
</table>

6. STRATEGIC PLANNING

6.1 To what extent are the following given attention during the strategic planning process in the school?

<table>
<thead>
<tr>
<th>Attention during Strategic Planning</th>
<th>1= no attention;</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
</tr>
</thead>
<tbody>
<tr>
<td>promoting links with industry for the purpose of acquiring research or development projects.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
<td>7</td>
</tr>
<tr>
<td>managing the research and development process in the school</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
<td>7</td>
</tr>
<tr>
<td>improving the capacities or capabilities of staff to undertake research/development work</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
<td>7</td>
</tr>
<tr>
<td>promoting entrepreneurship within the school</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
<td>7</td>
</tr>
</tbody>
</table>
7. RELEVANT DOCUMENTATION

We would appreciate it if you could enclose any documentation which you feel may be relevant to the survey, if these are readily available. In particular, copies of the following documentation will be most appreciated:

7.1 Policy documents pertaining to staff consultancy and patents and licensing.

7.2 A review of research / project work undertaken in the school, in particular those projects that provide good examples of technology transfer.

7.3 Details of collaborative research projects (or proposed projects) with industry and / or universities.

We would also appreciate it if you could provide the following information to enable us to track who our respondents are and enable us to follow up on any specific queries. We once again assure you of the complete confidentiality of your responses to the survey.

<table>
<thead>
<tr>
<th>TECHNIKON</th>
<th>RESPONDENT</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>e-mail address</td>
<td></td>
</tr>
<tr>
<td>Telephone #</td>
<td>Fax Number</td>
</tr>
</tbody>
</table>

We appreciate your time and cooperation in completing this survey. Please mail the completed questionnaire to:

Anthony Staak
Westgate Apartments C-5,
Cambridge, MA 02139
United States

ph #: (617) 494-9859
Fax #: (617) 253-7140
e-mail address: apstaak@Athena.mit.edu