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ALIGNING INNOVATION FOR DYNAMIC CAPABILITIES AND SUSTAINABLE GROWTH IN SOUTH AFRICAN MANUFACTURING

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Abstract

It is widely agreed that technological learning and innovation are essential features of successful economic development. Yet achieving commercial success through technological innovation is notoriously difficult. Sophisticated entrepreneurial, managerial and organisational capabilities are at least as important as technical capabilities for achieving and sustaining this. Policy decisions around innovation expenditure should emphasise commercial not technical success. Expenditure should not only assist the development of new technologies, products and processes but also consider the development of managerial capabilities for penetrating large, difficult-to-enter overseas markets. This is a particular challenge in the manufacturing sector where innovation has traditionally been inwardly focused. Overcoming this is extremely important as this sector holds the key to broad-based job creation.

1. INTRODUCTION

The main idea to be explored here is that exploiting technological innovation to generate economic growth depends chiefly on difficult-to-acquire management capabilities. Achieving commercial success on the basis of a technological innovation represents a considerable challenge facing managers and entrepreneurs. Repeating this is no less of a challenge. Organisations that sustain rapid growth over an extended period typically do so not because of great technology, but because of great management capability to exploit possibly second-rate technology.

The literature abounds with examples of overseas companies which have learned these lessons and acquired the necessary managerial capabilities, often through painful trial and error processes. By comparison, relatively little has been written about successful management and exploitation of innovation in South African companies. Nowhere is this more true than in manufacturing. Innovative professional services companies such as Discovery Health, Dimension Data and Investec are more likely to be singled out for attention than is a top-performing manufacturing company. Although innovative service companies play a vital role in the South African economy, it will be argued that manufacturing companies competing successfully in international markets hold greater promise for employment growth for the majority of our labour force especially those without tertiary education.

Ziton SA (Pty) Ltd (henceforth Ziton), a medium-sized Cape Town-based manufacturer of fire detection equipment, is a highly successful South African manufacturing company worthy of close examination. It has sustained rapid growth in both revenue and employment over the last 20 years. In the last 10 years alone, staff numbers have increased by 400%. The majority of jobs created are at relatively low skill levels. Innovation has played an important part in Ziton's success. Within a space of six years, Ziton transformed itself from a primary focus on the distribution of imported fire detection products to a world leader in design and manufacture of analogue fire detectors.

The Ziton story is far more than simply inspirational. It provides valuable and practical lessons in successful innovation management. Success did not come because of great technology. The ingenuity and determination involved in establishing credibility with overseas customers despite extremely limited resources and sanctions are far more remarkable. Entering and learning to compete in international markets was a slow, incremental process in which entrepreneurial vision, instinct and perseverance played crucial roles. The pace of Ziton's rise to international prominence received important boosts by selective use of government support programmes which carries its own lessons.

Many of the key features of the Ziton story are not unique. They fit a pattern of innovation management in successful companies abroad. Section 2 provides this international context. It briefly reviews some of the most important developments overseas in the field of innovation management. Section 3 reviews the key features of the management of innovation in the South African environment. It also considers how this influences growth in manufacturing in the South Africa, by reviewing some episodes of innovation in the South African electronics sector. Section 4 provides the details of technological and managerial learning at Ziton. We conclude in Section 5 by exploring policy implications.

2. WHAT HAVE WE LEARNED ABOUT INNOVATION?

The view that innovation is the lifeblood of a successful economy is taken as given here. A simple indicator of this is the rapid increase in the proportion of high tech, R&D-intensive goods in exports of industrialised nations (Keesing 1967, OECD 1986). Technological innovation has spawned whole new industries and destroyed others (Abernathy and Utterback 1978). Technological learning and capabilities are widely recognised to play an important role in achieving a defensible competitive position in a variety of sectors (Twiss 1995). It is also recognised that a technological capability is not sufficient for a defensible economic position (Tidd et al. 1997, Blankley and Kaplan 1997). This section explores the reasons why this is the case.

2.1. Innovation is a risky, unpredictable business

In essence, the challenge to successful management of innovation can be summarised as follows.[1] The probability of technical success in product innovation projects is 80%, whereas the probability of commercial success is estimated to be around 20% (Mansfield et al. 1972).[2] Combining these means that the probability of a successful innovation is 16%. Roughly five times out of six we expect a project to fail. This is considerably worse than the four out of five times we expect technical success from an innovation project.

The challenge looms larger when one considers that the cost of innovation projects is heavily loaded at the back-end (Wheelwright and Clark 1992). Table 1 shows estimates for the breakdown of innovation projects in a manufacturing environment. Basic research and product design and development work tend to make up less than 50% of total project costs.

In order to make maximum use of limited resources, the key managerial skills are the ability to reject unviable projects as early as possible in the innovation process and to contain the costs by avoiding rework on successful projects (Tidd et al. 1997). Empirical evidence highlights how difficult these can be to achieve in practice. Half of R&D expenditure in large organisations typically is spent on unsuccessful projects (Booz Allen Hamilton 1982). Cost overruns on successful new product projects are typically between 350% and 600% (Mansfield et al. 1972). Research on the survival of start-ups and small firms indicates that the overwhelming majority fail (Audretsch 1995). While a technology orientation in a start-up is likely to reduce the probability

[1] Innovation refers to the process of bringing new products, services or process to market. The 'market' requirement simply refers to the need for commercial application either within or outside the firm. This is the essential feature which distinguishes innovation from invention which could be considered complete before reaching commercial application. Following Schmookler (1966), Gerstenfeld and Wortzel (1977), and Hobday (1995), we view 'new' as new to the firm rather than to the world or the marketplace. This helps to maintain the focus on commercial impact rather than the proprietary or technological details around new product/ process development. Nevertheless, the distinction between pioneering and imitation innovation activity is considered extremely important when considering innovation in South Africa and this is reflected in the discussion below.

[2] Figures were calculated by comparing project forecasts with outcomes.

of failure somewhat, innovation does not necessarily reduce the probability that a firm will disappear (Cosh et al. 2000).

Table 1. Breakdown of costs of innovation projects

	Proportion of total project costs (%)
Research	1-25
Design, prototyping, testing	5-40
Production	10-60
Launch	20-70

Estimated from Tidd et al. (1997)

As if all this were not enough, history tells us that many of the most important and promising innovation projects are incorrectly rejected by the organisations that invented them in the first place and instead commercialised by other organisations (Christensen 1997, Garud et al. 1997).

2.2. For innovation to succeed, it should be aimed at big markets

Though obvious to some, the importance of big markets is often overlooked, even in surprising places like Silicon Valley (Komisar 2000). Nowhere has the importance of market size been more powerfully demonstrated than in East Asia. The importance of exports in Japanese development generally and in enabling Japanese companies to enter and succeed in technologically complex industries in particular, is widely recognised (Freeman 1989, Johnson 1993). The large, heavily protected but highly competitive Japanese domestic market also played a hugely important role as a "springboard" for the eventual export of advanced products (Mowery and Rosenberg 1989). Its importance can be seen by the fact that in those domestic markets which proved too small for economic levels of production, export-oriented industries often failed to materialise (Mowery and Rosenberg 1985).

Other East Asian development successes have adopted the Japanese export-oriented approach whole-heartedly. In the earlier phases of development, South Korea was able to establish key industries with the help of a heavily protected but competitive domestic market even though it was significantly smaller than in the case of Japan (Hobday 1995). However, the Korean markets were significantly smaller than those in Japan. As Korea proceeded with the establishment of more technologically complex industries and product capabilities, the domestic proved to be inadequate and companies were forced (often literally) into an early focus on export markets (Hobday 1995). Learning to compete overseas was far from straightforward and involved some spectacular failures, embarrassment and frequently heavy losses especially during early phases (Magaziner and Patinkin 1989, Kim 1997a). This pattern is also clearly evident in other, smaller East Asian tigers (Hobday 1995).

The East Asian focus on export markets is closely related to its orientation toward incremental innovation, often starting with duplicative and creative imitation (Mowery and Rosenberg 1989, Kim 1997a). Hobday (1995) provides compelling evidence that the Korean approaches of technological learning based on imitation and market learning based on intensive interaction with overseas customers were complementary and powerfully reinforcing. Imitation makes it possible to operate in relatively difficult-to-enter markets based on technological competition and the opportunity to export to high-wage destinations provides the basis for a defensible market position based on low cost production (Hobday 1995). Not only does the imitation approach reduce technical complexity (Kim 1997b), it also frees one from the notoriously difficult task of finding markets where none exist as yet (Christensen 1997, Iansiti 1998). This is especially true in the case of developing countries (Kim 1997a). The imitation orientation of these countries, though often portrayed in a negative light, and questioned ethically (Fialka 1997), has been put in its proper perspective (Lardner 1987 for Japan) and (Kim 1995 for Korea). It also became clear that Japanese had introduced major refinements to the management processes around imitation. A commercialisation based on external technology costs 50% less in Japan than one based on internal technology, while the cost is the same in the US (Mansfield 1988). This will be more fully discussed in the next section.

The success of a number of East Asian companies in penetrating overseas markets was met with deep concern (Hayes and Wheelwright 1993, Magaziner and Patinkin 1989, Dertouzos et al. 1989) as well as scorn (Krugman 1993, cited in Johnson 1993). This in turn has led to increasing emphasis on the importance of export markets for US technologies demonstrated, for example, in the controversial lifting of the ban on the export of strong encryption software.

2.3. Innovation must be embedded in manufacturing if it is to lead to broad-based and sustainable job creation

By 'broad-based' job creation we mean the creation of jobs across a range of skill levels. The argument around the importance of manufacturing is two fold. Firstly, the mix of skill levels that can be utilised in manufacturing is broader than in other technologically complex sectors. Professional service sectors, which have been among the fastest growth sectors, create remarkably few jobs at lower skill levels (OTA 1997, cited in Mowery and Rosenberg 1989: 206, Hughes and Wood 2000).

This is not to suggest that other non-professional service sectors are not significant employers of lower skill level workers. Certain service sectors, e.g. tourism, hold considerable promise for job creation, including at lower skill levels. However, non-professional service sectors are not typically viewed as important sites for the process of technological innovation (Hughes and Wood 2000). Also, comparing jobs requiring comparable education levels, wages for lower skill workers in non-professional service sectors tend to be lower than in manufacturing (Dickens and Machin 1999, Daly et al. 1985).

Secondly, the manufacturing function itself came to be seen as playing a critical role in the success and sustainability of the innovation process. The rapid growth of Japanese imports into the US market from the early 1970s provided an important wake-up call in this regard. Initially, the focus of attention was on the Japanese achievements in the manufacturing function itself and how this function could become a strategic competitive weapon (Schonberger 1982, Hayes and Wheelwright 1984, Dertouzos 1989). The most widely publicised achievements of the Japanese included uniquely high levels of quality, worker motivation and productivity. These were achieved through such management approaches as uniquely high levels of worker participation in improvement efforts, total decentralisation of responsibility for quality, the famous "just-in-time" inventory management system, dramatic reductions in batch sizes and an emphasis on production engineering as a means of reducing set-up times and thus bringing the "economic order quantity" down. The response in US and Europe, in part, was fanatical focus on productivity improvement and 'lean' supply chains in what came to be known as the "decade of downsizing" which was later recognised as having damaged rather than enhanced innovation performance (Caulkin 1997).

Emphasis later shifted to the Japanese ability to integrate design and development with the manufacturing function to reduce new product lead times, cut development costs and improve quality (Womack et al. 1990, Wheelwright and Clark 1992). New product lead times in Japan were down to as little as half those in the US (Imai et al 1985, Clark et al 1987). The Japanese have been noted for being the first to introduce a number of innovations based on US inventions (Mowery and Rosenberg 1989). Some of the widely publicised features of the Japanese approach include the importance of the engineering department (part of manufacturing function) in supporting the close interchange of information between those responsible for product design and those responsible for manufacturing technology, transfer of engineers between engineering and research laboratories during research projects, and contribution of experienced researchers and engineers to the development of younger engineers through project management (Mowery and Rosenberg 1989). To this might be added that many Japanese companies are noted for sending both design and manufacturing engineers in preference to market researchers to speak to overseas customers. The Japanese promote a culture of respect for the individual which enables "tapping the tacit and often highly subjective insights, intuitions, and hunches of individual employees and making those insights available for testing and use by the company as a whole" (Nonaka 1991). Nonaka also demonstrates that this individualised interaction results in a 'spiral of knowledge creation' as each employee contributes insights and refines collective understanding. Importantly, some of the earlier thinking around 'lean' was revised and greater emphasis was placed on slack, surplus (Caulkin 1997, Cusumano and Nobeoka 1998) and the need for 'redundancy' into organisations (Nonaka 1991).

All of the above insights have served to raise the profile of the manufacturing dramatically. Deep concern was expressed about the ability of US manufacturing companies to regain their competitiveness (Dertouzos 1990) and in particular their ability to retain the manufacturing function itself (Magaziner and Patinkin 1989). The tendency of US manufacturers to focus on research, design and product development and outsource manufacturing has been noted and the negative effect this could have on future innovation capability is a major concern (Magaziner and Patinkin 1989, Mowery and Rosenberg 1989).

2.4. Sustainability depends on "dynamic capabilities" acquired through continuous adaptation

The last 50 years have witnessed dramatic changes in management and organisational approaches to managing the risk in innovation. The period began with confidence in the large corporation as the central player in technological innovation

(Schumpeter 1942) and economic development. This conviction rested upon an assumption of the overriding importance of basic research for pioneering development activity (Kamien and Schwartz 1982) and a cost-centred view of innovation (see Cohen and Levin 1989). By the 1990s, the model of US innovation "science-based enterprise" had been severely shaken (Rosenbloom and Spencer 1996). One indication of this was the increasing pace of turbulence in the make-up of the Fortune 500 (Audretsch 1995). No major industrial R&D laboratory in the US came through unscathed (see Iansiti 1998 for a personal account). The defensibility of technological capabilities had been undermined by scientific foundations becoming increasingly pervasive, the narrow technological focus of traditional R&D organisations were misaligned with an exceedingly broad and complex science base relevant to a single product and increasing market unpredictability (e.g. around internet software) impacted heavily on scientific disciplines and knowledge bases (Iansiti 1998).

It is impossible in this brief summary to do justice to development in thinking around the management or organisational approaches to turbulent technologies and markets. It is instructive, nevertheless, to consider just a few strands. Important developments have been in the understanding of the "core capabilities" or knowledge bases which underpin innovation within an organisation. A firm's current knowledge base cannot be separated from how it is currently organised (Kogut and Zander 1992). Core competencies incorporate a number of different dimensions and levels, including resources, processes, norms (Leonard Barton 1992) and organisational forms and combinative capabilities (van den Bosch et al 1999). This has led to breakthroughs in understanding of how existing capabilities interact both to enhance and obstruct innovation projects and particularly how to address normative obstacles (Leonard Barton 1992). It has also formed the basis for breakthroughs in understanding how different modes of technological change, particularly disruptive innovation, are consistently discarded by technological leaders (Christensen 1997, Garud et al. 1997). At the same time, the understanding of core competencies with appreciation of the role played by value networks (Christensen 1997).

At least in the US, thinking along the above lines has formed the basis for two somewhat divergent but mutually consistent patterns of organisational response. Iansiti (1998), for example, demonstrates persuasively that both have played a central role in the renewal of the US electronics industry. On the one hand is the sphere of internal renewal, the remaking of established organisations. Central here is the distinction between exploration for new capabilities and exploitation of existing capabilities (March 1991). In order to sustain themselves, organisations have to leverage established routines during times of stability and re-invent themselves through times of upheaval, called managing "ambidextrously" (Tushman and O'Reilly 1997). Zack (1999) outlines the role of process and cultural dimensions in balancing exploration with exploitation. "Social capital" developed through people interacting repeatedly over time is shown to be crucial for effective renewal of intellectual capital (Nahapiet and Ghoshal 1998), much along the lines of Nonaka (1991). The ability of an organisation to reinvent itself happens incrementally, iteratively and in an interactive manner as the external environment changes (van den Bosch et al. 1999). The process of organisational change is not solely driven by creative management responses. Schrage (2000) demonstrates that modern technologies for simulation and prototyping have a profound impact beyond simply the product development process itself. They have begun to redefine how organisations see and understand themselves and can have a powerful influence of the evolution of the organisation itself.

A closely related stream of renewal occurs largely outside established organisations. In part, this is associated with the transformation brought about the army of technology-based start-ups (Audretsch 1995). An improved understanding of the normative obstacles to innovation in established companies has also led to deeper appreciation of the role of the entrepreneurially driven innovation (Utterback 1994, Christensen 1997). Start-up firms and entrepreneurial behaviour are playing an increasingly critical role in the commercialisation of radical or breakthrough technologies (Garud et al. 1997). A whole new industry to support and "incubate" technology start-ups grew up around leading research institutions (Rice 1998). At the same time a major upheaval was taking place in research institutions in the US to reposition for a changing technological landscape in which diverse technologies became increasingly integrated (Mowery and Rosenberg 1989, Iansiti 1997). A large number of US universities made deliberate changes to the way they approach the commercialisation of their intellectual property away from selling it to developing it by enabling students, alumni and others to commercialise it. There has been an explosion in the number of business school-, technology-based entrepreneurship centres together with growth in entrepreneurship course programmes from 20 to over 500 in the last 20 years. The strength of entrepreneurial culture and institutions which support high risk, technology-based entrepreneurship in the US together with the US strength in a variety of key technologies, including biotechnology, software and certain areas of electronics are now seen as key differentiating factors with Japan (Preston 1998). This is in sharp contrast with the development of processes for 'internalised' renewal, in which the Japanese have arguably led the way.

The purpose of this brief sketch of recent developments in thinking around sustainability in turbulent technological and competitive environments was to emphasise the centrality of creativity and adaptability on the part of managers and organisations. Technological change does not occur in isolation. It is deeply embedded in institutions. The for-profit company provides the key managerial, organisational and social context for innovation. The ability to reconfigure internal competencies to address rapidly changing environments is the essence of "dynamic capabilities" (Teece et al. 1997). Ultimately, these are the strongest basis for sustainable competitive advantage as they are the most difficult capabilities to imitate. Achieving this is beyond the scope of top management alone (Tidd et al. 1997) and require increasingly decentralised decision-making particularly in complex, pioneering technology environments (Iansiti 1998).

2.5. Summary

Arguably the most important mechanism for ensuring economic benefit from risky investment in technological innovation is to target large markets. For South Africa, this must logically mean a focus on export and more particularly overseas export markets, given the size of the Southern African market. Doing so would increase the probability that, for the small proportion of innovation projects which succeed, the revenue growth will be substantial.

For revenue growth to lead to broad-based job creation, innovation projects must be imbedded in manufacturing companies. But the importance of the manufacturing function goes far beyond that. It is an enormously powerful competitive weapon in its own right and has played a central role in enabling East Asian companies to gain entry to overseas markets through efficient, low cost production operations.

Focusing innovation effectively on large markets and developing a competitive manufacturing capability represent significant managerial challenges in their own right. Possibly the greatest challenge for managers and organisations, however, is to integrate and align these activities within the organisation(s) in such a way that the organisation is able to respond effectively to increasingly turbulent and uncertain technological and market environments. Research on dynamic capabilities is increasingly emphasising culture, value systems and norms, the importance of which were sometimes overlooked in the West. World-class innovation and manufacturing capabilities can become obsolete in a short space of time, and it is the ability to navigate organisations through both incremental and radical change that becomes critical to sustainability. Sustainability is difficult if not impossible to achieve without world class innovation and manufacturing capabilities, but on their own those are not sufficient.

Finally, it should be noted that there are no short-cuts to developing dynamic capabilities. A company might have the most creative culture, excellent communication and high levels of trust, but without the requisite managerial and technological capabilities to identify and address the needs of large markets, it is unlikely to become a dynamic operation.

3. INNOVATION AND GROWTH IN SOUTH AFRICA

This section considers how South Africa performs along key dimensions of innovation activity as identified in the previous section. We then evaluate the relevance of South Africa's innovation performance to its growth performance with a particular focus on electronics companies. Finally, the Ziton case is introduced with a brief outline of its growth performance.

3.1 Is South Africa successful at exploiting its innovation effort?

A number of indicators suggest problems in our ability to exploit our technological capabilities and effort. South Africa appears to be significantly stronger in science than in technology. South Africa's share of Science Citation Index is five times larger than its share of patents registered in the USA (Pouris 1991). South Africa's share of scientific publications is higher by comparison with most newly industrialised countries (NICs) (Taiwan excepted) and its share of patents lower (Joffe et al. 1995). It is likely that South Africa's share of innovations is lower still by comparison with NICs, but available evidence does not allow direct comparison.

South Africa's science and technology resources are more heavily orientated toward the development of new technology and radical innovation than is the case in the Asian NICs. This is consistent with the self-sufficiency "science republic" approach characteristic of the Apartheid era (Marais 2000). Although East Asian tigers are well known for an emphasis on imitation and incremental innovation, a strong novel technology capability is not in itself necessarily undesirable. However, university-based scientific discoveries rarely find any commercial application (Philips 1990). Attempts to establish technology incubators for high technology start-ups have not been unqualified successes. Anecdotal evidence from technology-based entrepreneurs suggests that a substantial proportion of patents generated at leading local universities have little or no commercial value and amounted to little more than a "CV building" exercise on the part of academics. Other anecdotal evidence indicates that a number of South African scientists continue to view Silicon Valley as the place of preference to commercialise their ideas.

There has been a marked shift toward greater emphasis on application of scientific research since 1994 (DACST 1996, p 11). At the same time, the importance of maintaining a basic research capability was emphasised (DACST 1996, p 9). This shift is laudable. In practice, the focus of spending remains on science councils and, to a lesser extent, universities. As shown below, these institutions are not always integrated with the private sector in an optimal way. Less than 10% of the Science Vote was allocated to the Innovation Fund, which is aimed specifically at the commercialisation of technology (Marais 2000). Further, in the first round of grants from this fund, less than one-third went to private sector organisations.

3.2. Is the South African innovation effort aimed at large markets?

At least in the case of traditional manufacturing industries in South Africa, the answer is certainly not an unqualified yes. In justifying the importation of foreign technology via license agreements, local firms are far more likely to argue that it will save in import revenue than that it will increase export revenue (Scerri 1993). Restrictive clauses in license agreements typically preclude licensees from exporting (Joffe et al. 1995). For those companies engaged in research and development activity, the target market for innovation activities is far more likely to be the domestic as opposed to foreign markets. In several of the more technology-intensive sectors, the share of newly introduced products was higher in domestic by comparison with export sales (Blankley and Kaplan 1997). Lastly, there is a long "science republic" tradition in South Africa of public funds for research being oriented toward local projects, including military technology and other "strategic" projects such as synthetic fuels. It appears that this culture has yet to be fully revised. A high proportion of Innovation Fund projects are focused on local projects, particularly those intended to address high crime rates locally (DACST 1999).

3.3. Is innovation embedded in South African manufacturing industry?

A prominent management educator argues that "many manufacturers do not have the technology, cost structures, knowledge or skills to deal with rapidly changing new technologies and competition." (Edwards 2000, p 60). Consistent with this, traditional manufacturing industries have tended to rely heavily on imported technology (Joffe et al. 1995, Wood 1995). Evidence suggests that, unlike their East Asian counterparts, local manufacturing firms which adopt imported technology are largely passive recipients of imported technology and seldom capture the necessary tacit knowledge to assimilate, adapt or transform imported technology (Joffe et al. 1995).

In terms of links with local research institutions, Joffe et al. (1995) found that a tiny proportion of manufacturing companies have research links with local science councils or universities. Blankley and Kaplan (1997) confirmed this and showed that the proportion is much lower among smaller firms. The fact that private sector R&D in South Africa declined between 1985 and 1995 (Joffe et al. 1995) is also suggestive of companies struggling to achieve good returns on such investment.

There is also concern about the level of embeddedness of innovation within the manufacturing function in those South African companies active in R&D. Joffe et al. (1995) refer to case study evidence suggests that technological effort is often isolated within the company largely to a separate R&D function, rather than being integrated within all activities of the company. Blankley and Kaplan (1997) found that with the exception of the smallest category of firm, production departments were far less important sources of information than either R&D or marketing. There is acknowledgement of a significant production engineering and operations management capability in a large number of South African companies (Joffe et al. 1995). Nevertheless, South African firms are said to be weak in shopfloor-based incremental innovation because firms engaged in R&D generally rank workers as the least important source of information for innovation (Joffe et al. 1995, Blankley and Kaplan 1997). However, Japanese manufacturing experts who are familiar with the South African manufacturing environment suggest that many South African managers were unrealistic about the impact which the introduction of Japanese-style, team-based shopfloor improvement methods. In Japan, less than 10% of productivity improvements are expected to come from the shopfloor. The onus for improvement is primarily on the shoulders of management.

Many of South Africa's most prominent recent success stories are professional service companies. "Companies such as Investec, Rand Merchant Bank and Didata are able to operate in the new technology. They are embedded with 'get-up-and-go' and 'we-can-do-it' attitudes" (Edwards 2000, p 59). These appear to depend on significant indigenous technological capability or backward economic linkages only to a limited extent and are said to succeed on the basis of South African "entrepreneurial spirit" (Edwards 2000, p 58). As noted above, the success of some of South Africa's professional service companies is relatively good news for those with the requisite high-level skills, but is unlikely to have much direct positive impact for those without tertiary education.

3.4. Manufacturing growth: The South African challenge

Despite obvious distress in several quarters of manufacturing in South Africa, there are some encouraging signs of improvement in performance. Probably the single most promising indicator is the growth of exports. As a proportion of total manufacturing production, exports grew from 10.9% to 16.9% between 1993 and 1997 (ILO "Impact of Globabilisation in SA" Database) and have continued to grow fairly strongly since. Export sales are accounting for the majority of the growth of total sales of locally produced manufactured goods, but this needs to be sustained and the pace of growth expanded. As is well known, growth in production has not been sufficient to offset productivity growth. Estimates of job losses in South Africa vary substantially, in some cases exceeding 500 000 since 1994 (Baskin 1999). Official estimates shown in Table 1 may underestimate the job losses in manufacturing. Table

1 shows that the electronics sector (in which Ziton (Pty) Ltd operates) has faired somewhat better in terms of employment levels than South African manufacturing as a whole, but for one of the highest growth manufacturing sectors globally the performance of the electronics sector in South Africa was mediocre.

Table 1. Growth in employment in South Africa manufacturing electrical and electronics products industry

	1990	1999	Change 1990-99	Change 1990-99
			%	% Compound annual
All Manufacturing	1 462 118	1 302 000	-11.0	-1.2
Electrical and electronics products industry	67 000	66 925	-0.1	-0.0

Bulletin of Statistics, 1991, 2000, Statistics South Africa.

It is not a simple matter to relate innovation and growth performance at a national level (Kim 1997a). The most comprehensive survey of innovation in South African manufacturing did not evaluate growth performance (Blankley and Kaplan 1997). Studies focused on individual industries and firms are more likely to reveal direct indicators of this relationship. In industries where significant export growth has been achieved, e.g. motor vehicles, it may be based on lower value added products rather than innovative capabilities (Barnes 1998). The sustainability of this growth is questionable. In certain metal products sectors, however, there is evidence of strong export growth on the basis of innovative products (Wood 1995).

Consistent with Section 2, there are also numerous examples where considerable investment has been made in technological development and yet the commercial and employment results have been disappointing. The reasons for this usually relate to one or more of the key requirements not being fulfilled; innovation is not focused on large markets, embedded in the manufacturing function, or harnessed and aligned to respond dynamically to turbulent environments. Below are some instructive examples of companies that have invested heavily in innovation in the electronics sector and who have not translated this into sustained growth for the local operation. Each is given a pseudonym.

"Diversified Industrial" invested more than R100 million in the development of an electronic product to augment its existing range. The R&D team involved in the development had relevant technical experience, but had never successfully brought a new electronic product design to market. After several years of false starts, expert assistance from Germany and the US was brought in to finalise and debug the design. In the end it took five years to complete development and prepare for manufacturing. Potential customers overseas were not involved in guiding development of the product; the product did not make it into overseas markets and had only limited success in the local market. Cumulated revenue from sales of this product did not reach one fifth of development cost four years after introduction. In the end, "Diversified Industrial" purchased a local competitor which had been first to market with a simpler product developed in a fraction of the time and at lower cost. The acquired company had been somewhat more successful in launching its product, having invested more resources in educating its customers in the use of the new product. However, its innovation had also been far from ideal. Market growth was misjudged badly. Three years after R30 million was invested in automated machinery, capacity utilisation was running at 10%. As with "Diversified Industrial", export sales had not materialised for the acquired company which had also finalised its design before extensive testing on overseas clients. In the end, the price paid by "Diversified Industrial" for the acquisition was a fraction of the original investment.

"Producer Electronics" has an impressive R&D capability combined with a competitive manufacturing operation. Its product development record includes some pioneering innovations. However, "Producer Electronics" has never had a major success in export markets despite numerous attempts. On more than one occasion, "Producer Electronics" has attempted to launch its South African products overseas, only to have its customers discover quality problems and incompatibilities with their systems and then be forced to withdraw altogether. Recently, big investments in pioneering products have been shelved as they were beaten to market by more focused competitors overseas. As a result of these cumulative failures, and a stagnant local market, "Producer Electronics" has shed thousands of jobs over the last ten years.

"High-tech Producer Electronics" has successfully introduced a number of advanced products in South Africa and developed its markets here. It lacked resources to develop overseas markets for its products. A decision was taken to develop these markets through a joint venture with a European company who undertook to manufacture the products under license and market them in Europe. After this arrangement had been successfully implemented, it became clear to "High-tech Producer Electronics" that the European company was obtaining valuable information from its European customers which it had not passed on to South Africa. This had enabled the European partner to develop superior products of its own and it subsequently stopped manufacturing those of "High-tech Producer Electronics."

In many respects, "Consumer Electronics" was and is an outstanding success. It introduced a novel product to the market. It was soon recognised to have numerous shortcomings, one of which was that it was too expensive for its target market locally. However, an alternative market overseas was discovered. The design went through several iterations which greatly improved the appeal of the product. Investment in manufacturing capability was low-key by comparison. It was largely out-sourced, and the few aspects where were performed in-house were prone to persistent quality problems. Little was done to improve the production capability. Production capacity was expanded in three different rounds, but each time the same processes were employed and the cost of production remained largely unchanged. "Consumer Electronics" struggled to acquire the necessary capabilities even to manage its local supply relationships effectively. A number of changes in the supplier base were made over time. The result was a relatively high cost, low quality manufacturing function. For a time, "Consumer Electronics" was able to get around this because the overseas market appeared to be willing to pay a premium for the novelty value and it enjoyed rapid growth in sales and revenue. They were forced to live with high reject and return rates. New manufacturers entered the market with similar products which put downward pressure on prices and margins. Over time, a decision was taken to expand production by out-sourcing it to an overseas company which can produce at substantially lower cost. The primary focus at the South African operation is product development which employs a small, highly-skilled team. “Consumer electronics” is involved in collaborative development of new products for entirely different markets. The South African plant lacks the necessary capabilities to produce these.

Having a strong manufacturing capability is not a pre-requisite for successful business. “Consumer Electronics” demonstrates that a very successful business model may be based on the outsourcing. However, it is unlikely to lead to broad-based job creation. It is recognised that by out-sourcing its manufacturing function, a company can significantly strengthen its competitor(s) and ultimately undermine its own existence (Mowery and Rosenberg 1989, Magaziner and Patinkin 1989).

3.5. Performance at Ziton SA (Pty) Ltd

Ziton SA (Pty) Ltd (henceforth Ziton) was chosen for study for the following reasons.

1. It has successfully introduced a number of innovations, including some pioneering innovations in its industry.
2. Ziton has targeted a large, relatively fast-growing market. In addition to having the lion’s share of the South African market, over 80% of revenues come from sales overseas. The company has a tiny share of the global market and hence there are few external constraints to its growth in future.
3. Ziton has developed a highly competitive manufacturing capability. The proportion of the value of its products which is added in-house has been rising steadily. This proportion currently stands at over 50%. In addition, a further 10% of the value of its products is added by local suppliers. Technological capabilities transferred from Ziton to its suppliers have enabled them to expand into new business areas, thus further enhancing the benefit to the local economy.
4. While employing a number of experts in different technology and management fields, a substantial proportion of the workforce has minimal tertiary education. This means that the model of growth which the organisation has pursued has shown economic benefits across a fairly wide stratum of occupation levels. As Ziton is the only South African company in its product area, growth in the company’s employment growth has not been and will not be at the expense of other South African companies. Ziton has never retrenched a permanent member of staff.
5. Ziton shows signs of developing dynamic organisational capabilities, particularly in the area of integrating its innovation and improvement activities across the different functions.
6. The Ziton story includes selected use of government support schemes. Had it not been for these, the pace of innovation would have been significantly slower which would have impacted on its ability to expand its export operation. This industry has received little by way of import protection. This means that the Ziton’s success is of great relevance to South African companies trying to establish themselves in the current context of tariff reductions and de-regulation.

The broad details of the company’s growth are shown in Table 2 below. Ziton has created 320 jobs in last decade. This translates into total growth in staff numbers of 400% over the period as a whole and compound annual growth of 16.5%. Ziton has achieved average annual staff growth of over 15% for each of the three decades since the company was started. Sustained growth in employment is overwhelmingly due to rapid growth in export sales. 250 people work in manufacturing and 210 of these are directly employed on the shopfloor in production and assembly. Educational attainment among shopfloor staff varies between Grades 7 and 12. By comparison with clothing sector workers, skill levels of Ziton shopfloor staff are generally higher as is remuneration.

Table 2. Growth in staff and revenue at Ziton SA (Pty) Ltd

	1970	1980	1990	1995	2000
Number of staff	2	10	80	150	400
Total growth over each decade (%)	-	400	700	-	400
Average compound growth pa (%)	-	16.1	20.8	-	16.1
Local sales revenue (R mill)				8	17
Export sales revenue (R mill)				14	80
Total sales revenue (R mill)				22	97

Source: Ziton SA (Pty) Ltd

4. MANAGING INNOVATION AND GROWTH AT ZITON SA (Pty) Ltd

4.1. Ambitious target: A large, difficult-to-enter, internationally-traded market

Annual sales in the fire detection industry worldwide amount to more than $600 million. Growth in the industry has been spurred by increasingly demanding stringent building safety regulations, initially in industrialised countries but increasingly in emerging markets as well. One of the reasons for the limited number of producers globally relates to the approval process. It is costly and time-consuming, as one of the Ziton directors explains. “Going through the UK test panel costs around R400 000 and takes 8 months. It involves a huge amount of work. This makes it a difficult industry to get into. You can’t sell for up to 2 years after commencing product introduction.” Entry has been made even more difficult by consulting engineers who demand increasingly sophisticated capabilities for fire detection, such as intelligent detection, remote diagnostics, self-test features, and wireless installation. 80% of sales worldwide now consist of sophisticated systems.

Back in 1969 the founders of Ziton, Robert and Margerett Macfarlane, had a dream of becoming a world leader in fire-detection. Thirty-one years later, Ziton is the smallest of 12 manufacturers globally in its product area with a global market share of around 3%. Given Ziton’s small share of the global market, there is enormous potential for sustaining growth into future. Ziton’s major competitors are based in industrialised countries including Switzerland, the UK, the US, Italy, France, Germany and Japan. Competitors in other East Asian countries are not particularly strong in this industry, tending to focus on consumer products. Fire detection products are relatively low volume and high value by comparison with the consumer electronics industry. Ziton is in a minority in the industry in its choice to incorporate design and manufacturing under one roof. Most of Ziton's competitors have shifted their manufacturing activities to lower wage destinations.

4.2. Establishment phase based on low value-added position, imitation and incremental development

The founders set up with total capital of R500. The original business focused on the installation of fire detectors, hose reels and fire-control systems. Initially, all the products were imported from overseas. Later, Ziton expanded the import side of the business to supply other local installers.

This experience was instrumental in the move to establishing a production capability. It provided practical experience of the issues facing end users and equipment installers concerning the critical performance dimension of fire protection products. It also provided a guide as to the most attractive product lines to target. Ziton ultimately focused exclusively on high value added products. In addition, it meant that Ziton knew in advance what unit cost level had to be achieved if in-house production were to be feasible. Crucially, it also provided a ready local customer base which would make it easier to achieve the required unit cost level. This was very important as growth in sales of proprietary products was slow initially and limited exclusively to the local market.

The founders lacked the required technical knowledge for product design or manufacturing. To overcome this particular problem, they began researching the subject reading books, magazines, pamphlets and anything else that was relevant. They broke down the imported products, found out how they worked and then set about trying to design and build basic functional products specifically for the South African market. Where they lacked technical expertise they employed the services of someone qualified to show them how they worked.

When production began it was on a fairly primitive basis. At each stage of development of the company, Ziton sought pragmatic solutions to the current challenges in production. 'We began to manufacture our own products at home. It was rather like a cottage industry. The detector, for example, has to be potted and requires a kiln. In the early days we used to use our oven so the kitchen was always filled with smoke detectors in the making.' Once the manufacturing process had been demonstrated, a production line was set up with three staff. Production techniques were fairly basic and each staff member had to be trained in the fundamentals of hand soldering. By insisting on a high degree of "home grown" component in production processes, Ziton established a fertile platform for encouraging rapid learning in-house in the area of production processes. This learning has instilled a high level of confidence in their capability to solve problems.

Ten years after start-up, Ziton had secured the bulk of the South African market. Their range consisted largely of imported products and the founders recognised the need to improve the design of their proprietary products which were primitive by comparison. The first recruit in design recalls his early reverse-engineering experience. "I was given a range of products from our overseas competitors. The first product that was developed was partly a crib of one of the best of these. Our first product took 6 months designing on a clip-on drawing board. That first product had a lot of metal parts and we hand made the jigs for spot welding. We used a taped-up circuit board for testing - we had no computers in those days. We built our own wind tunnel and a primitive smoke chamber for testing. The modern day equivalent smoke chamber cost us R2m."

Ziton's first designer had never designed a product before and it showed. "When I look back at that I cringe with embarrassment. I knew so little. I didn't even know anything about plastics moulding. Before prototyping, the drawings came back from the draftsman with angles added on to facilitate release during moulding." His background was in production in the electronics industry. This recruitment choice was deliberate. At his interview, he was asked to make rather than design something. The fact that he had dropped out of an electrical engineering degree was not considered important. Being able to bring a product into production quickly was ultimately more important than the finer details of design. Designing and building jigs and devising a home-made circuit board tester were the critical skills at that stage. This recruitment choice was further vindicated. Fifteen years later when complex and novel design capabilities had become far more important, the same person was at the helm of design as well as bringing products into production. Ziton's founders appear to have a special talent for identifying people with a combination of appropriate experience and remarkable skills. This has been crucial in the company's development.

4.3. International market entry based on direct, timely contact with foreign customers and incremental development of overseas marketing and distribution channels

Closely following Ziton's launch of its second conventional detector[3] in 1980-81, one of its competitors threatened legal action for illegal use of patent information. The design had to be adjusted to get around the patent. Undaunted, the founders took the product overseas to explore the potential for entering the export market. They spent six weeks in the UK in 1982 during which time they met with hundreds of potential customers. The founders received help in making the right contacts from a UK manufacturer who they acted for in SA. He gave them his complete customer list. They visited every single player in the fire detection industry and related industries in the UK. This visit turned out to be highly fortuitous in guiding the future direction of product development. "Near the end of our visit, one guy asked us what we were doing about analogue systems,[4]" explained Robert. "He suggested to us that these are going to be the future for the industry. He had heard of a European company thinking along those lines. Nobody in our company had thought of the concept. It was such a major advance, it could not be called incremental. On our return, we set about employing a local engineer to develop such a system. Ours was the first system in the world, introduced in 1984. It was crucial to our entry into the international market. We were followed by Siemens and Antronica."

Important as product technology was, success in the overseas market did not simply follow. "People were wary of us being from South Africa," remarked one of the founders tellingly. "It took 5 years to convince people that you could get technology out of South Africa." Ziton's strategy for entering export markets was to

[3] Conventional refers to the fact that the detector is not part of a programmable system.

[4] These are computerised or "intelligent" systems which are referred to as analogue because of the way in which they measured smoke.

focus initially at the bottom end with conventional detectors. The markets and technology for these are far simpler. Customers buy these products "off-the-shelf." Agents are not required to provide any technical back-up or after-sales support. This dramatically reduces the cost of entry and also eliminates much of the risk on the part of the agent. As a result, agents have little loyalty to their suppliers of conventional detectors. Competition in the market for conventional detectors is very much price-based. In 1984, two years after the exploratory trip, Ziton recruited agents for its conventional detectors, offering a lower price compared to alternative products. The agents took the products on a trial basis. Ziton needed to prove itself to agents in terms of delivery, product quality and ultimately persuade them that Ziton was in it for the long term.

While Ziton's conventional detectors were being launched into export markets, the new generation analogue detectors were tested in the South African market. Substantial improvements to the software were made during this period. Only after one year of successfully selling conventional detectors overseas did Ziton persuade agents to take their analogue detectors. "Some people just laughed at us," recalls one of the directors. Agents representing their analogue range were required to sell Ziton equipment exclusively. At this time, Robert's brother moved to the UK to establish an office there to recruit and manage relationships with agents and end-users. Ziton invested extensively in training its agents from its global marketing base in the UK. For existing agents it foots the entire training bill, whereas for new recruits, they are required to pay a proportion of the cost. For the first 4 years, the company was not able to afford to provide technical support from the UK, and opted instead to fly technicians from SA whenever they were needed.

In the fire detection industry, product innovations tend to confer a relatively temporary advantage. Ziton's introduction of the world's first analogue fire detection system gave them a technological lead for a period of about 4 years. During that time, competitors introduced comparable features. Ziton's has invested heavily in expanding and enhancing its product development capabilities since the launch of the first analogue system. The product development effort has meant that Ziton has been able to increase the proportion of proprietary products in its range, from a small fraction of the total to over 80% today. This is an extremely important feature of the Ziton story. The risk associated with investment in new product development is dramatically reduced when one already has an existing customer base for the product and extensive prior knowledge about customer needs and the direction of technological change in the market. Virtually all of the risk of commercial failure is removed and the projects face only technical obstacles to success, which as shown above, is usually considered to be a minor portion of the total risk.

4.4. Ziton and government support for innovation

Ziton has benefited from awards under the government's Support Programme for Industrial Innovation (SPII) as well as loans under other innovation support schemes. In the view of the founders, Ziton would have succeeded without this assistance, but the funding enabled it to "get there more quickly". As will be seen below, speed is crucial in this industry, so the importance of this support should not be underestimated. It is worth noting that in spite of the importance of early contact with foreign customers and the cost and risk associated with this, Ziton has never made use of government incentives for overseas marketing. Given the administrative burden associated with claiming these incentives, they were regarded as ultimately not worth the trouble. Ziton has also not sought technical assistance from any science councils, but continues to benefit from contact with local universities, discussed below.

4.5. Process engineering capabilities essential for building capacity and sustaining competitive position

Even for a company with world class product development capability, the importance of capabilities in the area of production and process engineering should not be underestimated. These are a crucial source of competitive advantage. Amongst other things, a sophisticated process engineering capability has enabled Ziton to expand capacity at lower cost (and hence more quickly) than would otherwise have been possible, adapt new equipment quickly to overcome unexpected problems, introduce unique process innovations, and achieve significant unit production cost advantages against competitors. There are so many examples of Ziton's achievements, it is possible only to give a few illustrations.

The introduction of surface mount device (SMD) manufacture meant that a "conformal coater" was needed to apply protective polyurethane coating to the assembled boards. An in-house manufacturing technologist started investigating possible suppliers. "We couldn't afford the coaters available from overseas at that stage. I suggested to Robert that it would be possible to design a machine ourselves. He gave me the go-ahead to try. So we did the design in-house and sub-contracted the manufacture to one of our local suppliers. Other manufacturers got to hear about this machine and our supplier sold four of those machines. We got the royalties for our design."

Ziton has collaborated with suppliers around the introduction of process innovations. One example of this is in the area of masking, a process which covers sensitive components with a protective substance prior to coating. In the past, Ziton used a latex rubber which was applied from a hand-held container. The latex took 20 minutes to dry, causing delays and increasing work-in-progress. Production staff noticed an article in an industry magazine, hinting at a new plastic material for masking. Enquiries were made and it was found that no material was available yet, but that Henkel Germany were working on a new material. Ziton contacted them, and offered to test formulations which Henkel was developing. Henkel assisted in the installation of a dispensing machine manufactured by Nordson. Following months of trial and error testing, a suitable blend was identified which met all of Ziton's requirements. The new material which is a Silicon-like, temperature-hardening plastic (Polyolifin) is called HotMelt. It takes 20 seconds to dry, which is 60 times faster than the latex. In addition, the new material is one-third the price of the latex. Finally, the new dispensing machine is faster and results in more accurate masking.

Ziton purchased new circuit testing machine called a Flyprobe tester in 1998. This allows greater flexibility in new product introduction as a test programmes for a new product can be produced in a couple of hours. The old system required a minimum of 5 days of jig designing and building, but this often took several weeks in practice. Despite extensive research into the choice of their flyprobe tester, the implementation was still not without problems. “Our boards are quite thin. We found that the boards were bouncing on the granite floor. Our mechanical design expert developed a vacuum support system. He got the idea from vacuum supports on the screen-printing machine for the SMDs (Surface Mount Devices). But those vacuum devices are much simpler as they are permanently on. He developed a system which used special sensors to trigger the vacuum at the appropriate time and minimise the consumption of compressed air. The Italian manufacturer has seen our adaptation and is now fitting the same device to their machines.”

Ziton’s manufacturing capability has received overseas recognition. In 1995, Ziton was approached by one of its largest competitors which was considering outsourcing part of its fire detection business and was interested in investigating Ziton as an option. The company sent 6 people to Ziton for a week. They investigated all aspects of the business to satisfy themselves that Ziton was capable of undertaking production on their behalf. Ultimately, an agreement was reached by which Ziton would manufacture slightly modified versions of certain products in its range which would be marketed in Europe under the competitor’s name. All but one of the components in these were to be designed and manufactured by Ziton. The partner benefited from enormous cost savings in this process. During the week of the original visit, the foreign team estimated that Ziton’s unit cost of production was less than 20% of that in their own plant.

The dual strategy of product leadership and price matching is an essential part of the longer term strategy of becoming one of the foremost manufacturers in the industry. It requires that Ziton has no weaknesses and ultimately that the organisation can match all competitors in terms of products and cost. According to one of the directors, “the combination is hard to beat.” Prices on competing products have been falling at the rate of about 4% per annum on average. Ziton’s view is that competitors are cutting into their margins in order to maintain sales volumes. Ziton’s dual strategy enables it to maintain margins. Product innovation makes it possible to maintain prices while productivity and quality improvement help control costs. Ziton avoids cutting prices, except where this is justified by cost reductions. Ziton did not post price increases between 1998 and 2000.

Ziton achieves high levels of productivity growth in production. An industrial engineers gave these figures for the two assembly lines for which he is responsible. Output on one line has been raised 77% from 450 to 800 products per day with the same number of operators. On the other, output has risen 50% from 500 to 750 products per day.

4.6. Productivity growth and job creation

Much of the productivity growth has been achieved via reducing the labour input requirement per unit of production. For most of Ziton’s history, growth in production and revenue has more than off-set productivity growth and the company has continued to take on more staff. More recently, recruitment has tailed off despite continued strong growth in production. Staff numbers in Ziton are levelling off and in the view of the production manager could conceivably decline in future. In part, this is due to increasing levels of automation. This needs to be considered in its proper perspective.

Firstly, Ziton has proven that it has the management capabilities to achieve international competitiveness with low levels of automation in production. The workforce quadrupled in size over the last decade. Secondly, Ziton avoids excessive automation beyond what is economically optimal. Ziton uses intermediate production technologies which are operator-assisting rather than fully automated. Thirdly, when the economics around a process necessitates increased automation, the company does not hesitate to do so. After being held back for some time, a project is underway to automate the production of the detector base. The machine to automate the process will be designed in-house as will the re-engineered product. As a result of this automation, staff in the section will be reduced by 75% and capacity increased by 50%, resulting in a 6-fold increase in labour productivity. The production manager adds, "We are continually analysing whether our current approach matches the local realities. We take into account a wide range of issues such as absenteeism when considering further optimisation in production. We are concerned that it is becoming harder rather than easier to maintain productivity levels in the Western Cape." Finally, the steady growth in revenue has meant that the staff whose tasks are replaced by automated processes have mostly been re-deployed in other areas. For example, sixteen people currently employed in the production of the detector head will be moved into other areas.

4.7. Tapping and filtering foreign market knowledge

The directors are clear about their main source of ideas. "95% of innovation is triggered by events outside the company, something heard, something read, something seen." The business is structured to reflect this reality. Ziton keeps close to its customers, mostly through its extensive network of direct agents. They currently have around 400 worldwide, of which half are overseas. Ziton's reputation with agents is so good that it is frequently approached by agents wanting to switch to Ziton products. As a result, Ziton has stopped actively recruiting agents in countries in which it is already operating. It still has to recruit actively when it moves into a new market. The agents play a crucial role in providing information on customer needs to inform product development priorities. "Consulting engineers are blessed with vivid imaginations and they sometimes call for way out things. Occasionally they generate some really good ideas. The agent comes to us with the specifications and we have to make a decision. The key issue is that our agents must be good enough to recognise good ideas as well as have a good enough reputation to get good jobs to learn from."

The founders emphasise that one of Ziton's greatest strengths is their focus on a specific niche. "You have got to know your customers and markets in great detail. You can't understand a wide product group. Fire detection equipment sounds boring and unobtrusive. But it requires an enormous amount of knowledge and expertise. When we check our competitors' products and go to trade shows, we really understand their products. Customers have real problems and face lots of issues. Almost all of these are addressed by every competing system. But we suddenly realise that somebody has solved a problem really well." Ziton handles enormous volumes of technical queries, product requests, etc. Calls from South African agents alone average 250 per week. Responding quickly and effectively to these is a challenge. The technical support department, whose staff have previously worked in R&D or system design, performs a preliminary analysis of all the information coming in from agents and customers all over the world. Failure trends are constantly analysed to pick up any major problems quickly. Product queries and problems are categorised and distributed to R&D or production or handled by technical support.

Ziton is highly selective about which new products to develop and which features to introduce. The majority of product requests and suggestions are eventually rejected. Critical to Ziton's success is the ability to make correct choices about which new product ideas to pursue. These decisions draw upon 30 years of experience in the industry and extensive knowledge of a global customer base. If it were not for this breadth and depth of experience, combined with the volume of information coming in from agents, the quality of choices would likely be compromised.

4.8. Tension between creativity and the need for speed

Another important advantage of customer-focused new product projects is the greater clarity that this introduces for the project team in terms of tight specifications and immovable deadlines. Limiting the scope of R&D projects is vital if lead times are to be kept short. In an area where technology is changing rapidly, this represents a significant management challenge. Ziton has 20 engineers in design and development, five of whom do genuinely original work. A number of their proprietary products are patented. Ziton builds in unique features into many of its products. Ziton's capabilities in product design and development are acclaimed both locally and overseas. At the 1999 Firex Show in Birmingham, UK, Ziton was given two Best Design Awards for its Horn Sounder, and Dual Sensor (see Exhibit 1). This is a source of tremendous pride to the designers. Their desire to "push out the envelope" is a strong source of motivation but also needs to be managed carefully.

In the past, Ziton has had projects which have dragged on for up to 4 years. The Macfarlanes are open about the fact that new product lead times are not yet sufficiently short at Ziton. "It is the norm for us to be six months late." Without a tight scope, there is always the danger of R&D staff adding new capabilities and features and never reaching closure. As Robert puts it, "It is hard to stop people being creative and designing over the top. New ideas can be a real pain and have to be managed carefully. The hidden cost is time. A job can quickly grow from 8 hours/day to 20 hours/day." For this reason, Robert prefers not to refer to his section as an "R&D" department. "We call ourselves design and development. The focus is on looking good, having the right features and excellent performance. Along the way people come up with new ideas, but that is not the focus."

Creativity and closure require a delicate balance in the cutting edge design environment. Ultimately, mutual confidence in the ability of ones colleagues and the quality of personal relationships will be determining factors. As a project leader in design and development (D&D) explains, "I get my brief from sales, customers, mostly via Robert. We work well as a team. Underlying that is a strong element of trust. Sometimes I go too far. I realise I'm going down the wrong road and I have to go back to basics and do what's just enough. Sometimes I only show him the design after I've finished it." Top management trust and confidence in key individuals in design and development is such that they are given tremendous scope to make their own decisions regarding expenditure. "Robert is indulgent in D&D ... I am out on a limb. I have total autonomy. I don't have to work to a budget, or only roughly. I have to work responsibly, not recklessly, but I'm allowed to grab for the order book." The record suggests that this policy does have significant benefits, including financial ones. In a recent development project required a special piece of test equipment, costing over R0.5 million. The team was given the freedom to explore alternative options to off-the-shelf version. They decided to design and build one in-house, for less than a 20th of the cost for the off-the-shelf option.

The time pressure associated with development projects can make collaboration with research institutions difficult. A Professor of engineering at UCT was asked to give advice in the design of a new product. He also assigned the project to a Masters student for his thesis. By the time the thesis was completed, the product had been launched and gone through at least one design iteration. As a result, the director was reluctant to have yet more ideas introduced to the design team. However, the project leader insisted on reading the thesis which concluded that it was possible to design 50% better performance into the product. The leader was also successful in persuading the head of D&D to grant a budget to employ the student for 6 months to explore further design improvements.

Occasionally, Ziton reinforces strong motivation of D&D staff by sending them to sort out the teething problems on site in the early phases of a new product introduction.

4.9. Managing quality in the context of rapid innovation

Quality refers to the total conformance of all finished products to the design and manufacturing specifications. Effective quality systems are essential for achieving reliable products, as Robert explains, "The increasing pace of innovation does effect production. The major difficulty in manufacture is reliability. The first three months are always consumed with debugging. Hence, trace-ability in the field is a major issue and problem for us. We have serial numbers, job numbers and exact model and version." Achieving repeatability quickly is essential to avoid inconveniencing customers and expensive recalls.

If the quality issues are not thought through at the design stage, then an assembly process may interfere with an already installed component or scratch the printed circuit board (PCB) surface, etc. Ziton seeks to ensure that risks of poor quality are designed out of their processes and new products. Industrial engineers provide a support function to D&D, assisting in the process of introducing a new product into production. They give feedback to designers to achieve required quality. Industrial engineers also produce the manufacturing manual which includes an assembly process flow chart and a quality plan. This manual defines the critical features of the manufacturing process from the point of view of quality as opposed to the functional or test perspective. The industrial engineers write the manufacturing manuals using the product manuals, written by design team members. Process specifications are also drawn up in the context of the forecast volumes and test parameters. This is necessary for optimising the economics of the processes chosen to produce a product. The industrial engineers write up the specifications for any new equipment required and normally produce designs for any tooling, jigging and fixtures. Sometimes, the design team do this themselves, particularly if these are required for the prototyping process.

Ziton is currently introducing three totally different products each year. The challenge of achieving effective and problem free introduction of new products into production increases dramatically with pressure on lead times as the Production Manager explains. "Keeping up with ongoing design changes is one of our biggest challenges. Some complex changes may require relaying out the lines, retraining people. The latter takes substantial time. If the time pressure for getting a new product out is too tight, then they might give us a board design that "works" but not to all specs. Then product revisions result in additional complications for us."

4.10. Threats from an increasingly turbulent environment

In the early 1990s, a UK competitor developed a special sounder. These are traditionally heavy current devices which require separate circuits for operation. This manufacturer developed a highly efficient siren which could connect to the same wires as the detectors. The directors saw the new product at the time of launch, weighed up its merits and concluded that it would not be important in the market. In the end, it turned out to be a huge success. Ziton started to loose tenders and their agents pressurised them to introduce an equivalent product as soon as possible. Ziton was faced with a stark choice on one particularly large tender for a hospital. The Ziton range could meet all the tender specifications with the exception of the sounder requirements. It was offered the tender if they were able to meet these.

A decision was taken to develop the sounder for this particular customer. The contract included a tough penalty clause for late delivery. The client faced an unmovable deadline in the form of a royal dignitary to conduct the official opening. This created enormous pressure within Ziton, akin to a Hyundai-type "crisis" (Kim 1997a). One of the advantages of this approach is the motivational effect, the challenge of meeting an extraordinarily tough project schedule for a big prize, i.e. a large order which would not otherwise have been possible. This appears to have played a part in persuading key members of the D&D team to work on this project day and night over a period of 6 months.

The team leader describes the introduction of the first sounder. "By the time the first sounder design was complete, our customer was 5 weeks away from facing very substantial penalty clauses. We worked several nights in a row. We had designed completely without paper. There were no drawings in sight. Those are needed for ordering, controlling, tracing, etc. As a result, I had to run the lines for one year because the drawings were not available and no-one else had the necessary information to run the lines for us."

Describing the same events from a production point of view, the Production Manager recalls, "I certainly felt the impact on productivity. It took forever to build the first design. We couldn't achieve repeatability. There was inconsistency even in the bare boards. We used to have scrap boards galore. It took a lot of work to get that one out. It's specs were open. It did X, Y, Z and a whole lot more."

At first it appeared as if this decision may have backfired. Debugging was a particular problem on the first sounder and Ziton was forced to recall several thousand of the products before all the faults were ironed out. It had to pay damages to some of its clients. That sounder design went through four revisions before it was stabilised. The resulting pressure was widely felt, as the production manager explains. “We are very strong in new products. Losing lead time means losing customers. But it can demoralise staff. The supervisors sometimes go wild. Sometimes we have to do a lot of overtime. They ask: ‘Why are we doing this?’ The importance of new product introductions for future success of the company are not always spelt out to us. Our operators want to know about the products.”

4.11. Dynamic capabilities in the making

The true test of an organisation is its ability to learn from such crises. Ziton learned important lessons which led to far-reaching changes. It has taken enormous strides toward effective integration of the design and manufacturing functions. Referring to a derivative product of the original “base” sounder, one industrial engineer paints a radically different picture. “The sounder started out properly. We drew up a checklist for D&D. We developed a good relationship with the project leader in D&D. We would go to him for advice and vice versa. We were brought in about half way through the project, two months before the product was coming to the factory. That way, we could be certain of the jigging being completed in time.” The checklist referred to contains all the critical criteria with which new designs must comply have been collated into a document for D&D. This enables D&D to design appropriately according to the limits and constraints of their manufacturing equipment. The production manager concurs with the improvements. “There has been a big improvement in getting the product manuals out on a timely basis.”

Tighter co-ordination of the work of D&D and production has a direct positive impact, perhaps most obviously in smoother introduction of new products into production. This is an important achievement in its own right. However, effective integration of different functions can realise powerful additional benefits. An important feature of this concerns the quality of relationships which exist within and between the different functions. Trust and mutual respect for colleagues in different areas is recognised as being crucial for ensuring that projects obtain the necessary support. The reverse can also apply. Staff experience of effective interaction within and between functions on successful projects can be a powerful means to increasing the levels of trust and respect (Leonard-Barton 1992).

This is a particularly important source of motivation for staff who may have felt under extreme pressure in the past. “We used to get called in when a product was ready,” remarked one of the industrial engineers. “We’d be told, ‘Here’s the product, here’s the manual.’ But we would be thinking to ourselves, ‘How do we build this, we haven’t seen this before.’ Now we are invited in at an earlier stage. They tell us how the product was conceptualised, developed and how to put it together. They also tell us when a new product will be coming to the line.”

Increased involvement in new product introductions into production appears to have had an enormous positive effect on the confidence and motivation of the industrial engineers. The senior industrial engineer spoke proudly of his proposal for a major project to improve productivity in the assembly of widely used component which had recently been supported and was underway. Increased trust has meant they are less reluctant to ask for assistance if they get stuck. This is likely to aid effective diffusion of skills across the organisation. One industrial engineer commented that their relationship with the test and measurement department had also improved and that they were communicating far more effectively to avoid misunderstandings over ongoing minor changes to manufacturing processes.

Similar changes appear to be occurring with D&D. The chief mechanical engineer explained. “The D&D green areas meeting was introduced for the first time this year. We meet every morning; 2 software engineers, 2 hardware engineers, Robert and myself. Before we were all on our own track. Now we are sharing where we all are and what problems we are facing. We are starting to cover ourselves a bit now, shoring up in our weak areas.”

New projects are underway to concurrently re-engineer products and processes which will bring about significant reductions in unit costs. These bring together representatives from different functions to identify solutions which are broadly supported. This way, different functions are changing and adapting their processes to reduce overall complexity and avoid choices which conflict with the needs of other sections. Take this example. Production has been experiencing problems with controlled torque equipment used to fasten the screws which hold the assembled boards to the outer casing. This equipment is prone to inaccuracies. They have had the supplier in on several occasions, but have reached the conclusion that there are inherent deficiencies in the present system. To cope with this, every single screw is being manually tested to check torque levels, which requires an additional member of staff on each line. A cross-functional team to address the problem has proposed changing from screws (and pins) to rivots which are cheaper and easier to fasten to tight tolerances. This may sound like a minor change. However, it has implications for a number of different sections. The rivot system will mean that it is no longer possible to remove a board once it has been fixed to its casing. This in turn has implications for rework and recall policy. Changing to a rivot system will probably also mean that Ziton has to re-apply for approval for the effected products. It is estimated that this change could save as much as R1m per year.

In 1999, Ziton began to seek further unit cost savings by more effective integration of the design and purchasing functions. As component prices are strongly influenced by order volumes, Ziton already achieves some purchasing advantage by linking with other manufacturers that purchase identical components. It has been recognised, however, that there is potential to reduce component prices further by increased standardisation of component purchases. D&D is now required to maximise its use of standard components in new product designs.

Ziton attempts to keep both production and D&D well informed about innovation among its suppliers and potential suppliers. Robert gave this example. “We have been moulding plastic parts for 20 years. Someone saw an advert for a plastics show (K2). Some of our staff went to the show and immediately realised how much more specialist other companies were in this area. We built up a huge list of contacts as a result of that show. Now when we have a problem, we don’t phone a local representative. We phone the world expert in Beyer in Germany. That way we solve a problem in 10 minutes that might otherwise have taken weeks. There is so much innovation going on in the world.”

This is not to suggest that there is not still enormous scope for further improvement in the level of integration and co-ordination within and between the functions. But Ziton has taken tremendous strides toward improving communication and co-ordination. The fact that this has been difficult to achieve is a credit to the organisation. Achieving effective integration and through it dynamic capabilities whereby each function is continually improving and re-inforcing the other functions is widely recognised to be extraordinarily difficult. Once achieved, they are also recognised to be a powerful competitive weapon, partly because of the difficulty of recognising let alone replicating such capabilities.

4.12. Summary

In today's competitive environment, no company can take its position for granted. We have all witnessed award-winning companies be acquired or disappear. After gaining international recognition for its product development capabilities and making rapid progress in expanding its export operation, Ziton was suddenly faced with a serious competitive threat. Responding to this threat demanded the full attention of Ziton's best managers, engineers, supervisors and shopfloor staff, so much so that months of working day and night ensued. Few staff were spared the considerable pressure and tension created by this project. It highlighted major shortcomings in the quality of communication between and within functions, perhaps most particularly in the processes involved in bringing a new product into production. Inadequacies in this area and in the development process itself resulted in a product launch fraught with problems and unnecessary costs.

This crisis appears also to have been a catalyst to the organisation making important breakthroughs in a number of areas. The quality of communication and relationships has seen significant improvement in certain areas. Levels of trust have increased. There is better understanding across the organisation of the difficulties faced by each function. Equally there is improved understanding of the needs as well as the capabilities in different functions. In part as a result of these changes, substantial improvements have been made in reducing new product lead times, reducing the number of design iterations, and increasing the pace of unit cost reduction, amongst others. Ziton is well on its way to developing a "spiral of knowledge" (Nonaka 1991). The dynamic organisational capabilities that Ziton has begun to acquire could arguably prove to be its most enduring and defensible sources of competitive advantage. This is particularly so in the light of the fact that few of Ziton's competitors combine product development and manufacturing under one roof and thus potentially face greater obstacles to achieving such dynamic capabilities.

Viewed in these terms, the opportunity to face this crisis was a privilege. But it was a hard-earned privilege which came about through years of painstaking building and nurturing. Were it not for Ziton's network of foreign agents, its reputation with overseas customers, its recognised product development capability, and the quality, reliability and sophistication of its products, this crisis and the opportunity to learn from it would never have arisen.

5. CONCLUSION AND RECOMMENDATIONS

In line with the development of thinking around the management of innovation overseas, Ziton provides a number of important and valuable lessons for entrepreneurs, managers, investors, policy makers and others. Given the focus of this conference, however, final comments will be focused on policy issues.

Relatively few South African manufacturing companies have achieved international success in large, difficult-to-enter markets. An important aim of innovation policy should be to encourage more South African manufacturers to acquire the necessary managerial and technological capabilities to achieve this. Put another way, the purpose of innovation policy should be to create an environment in which large and increasing numbers of companies have opportunities to develop the combination of technical skills and dynamic managerial and organisational capabilities necessary for responding effectively to the competitive crises which inevitably will arise. How could this be achieved in practice? We consider some options below.

5.1. Commercial, rather than technical success is the most challenging aspect of innovation and also the only objective

This is stating the obvious, but it still bears repeating. For example, the criteria used recently to evaluate the innovations by SPII grant holders were partly technical. Commercial success appears fourth on the list, after "adherence to budget and time scales," and "level of technological risk." This approach muddies the waters. Only commercial impact really matters, and hence the focus of attention should be revenue, profit and jobs generated.

This point is highly relevant to the orientation of policy. In general, the resources required and the risk involved in developing markets for a new product, suitable channels through which to service customers and learn from them are far larger than to develop the product in the first place. Significant numbers of South African patents, products and technologies are not fully exploited because of the vast cost and risk involved in developing overseas markets. "High-tech Producer Electronics" is a good example of how an investment in a new product can go to waste through lack of resources to commercialise it effectively overseas.

Given the above and the evidence from Blankley and Kaplan (1997) on the lack of inward focus of innovation, it is quite possible that the revenue generated by every Rand invested in developing overseas markets for promising, but not fully exploited South African technologies would be higher than for every Rand invested in developing further technologies. Again the Ziton case is instructive. Once the overseas markets were opened and the channels put in place, the risk of every additional innovation project was dramatically lower. The overall project risk began to approach the risk of technical as the risk of commercial failure was substantially reduced.

This is not to suggest that we should stop investing in developing new technologies, but rather that we should invest more in developing international markets both for our current and our future technologies. What this means in practice is that we should seek to create more opportunities for entrepreneurs and managers to acquire the requisite skills to gain footholds in difficult-to-enter overseas markets. The implications of this are developed further in the following section.

Finally, it has been suggested elsewhere (Kaplan 2000) that tax rebates for R&D would be an effective means to encouraging innovation in South Africa. However, if the limiting factor is resources for developing overseas markets, then R&D incentives might not be best placed to generate revenue growth.

5.2. Evaluate public investment in innovation by the size of the growth opportunity and the probability of commercial success

The export-oriented company focused on large, difficult-to-enter markets is the primary site of sustainable revenue growth. Being export-oriented is definitely not sufficient. A substantial proportion of South Africa's exporters are in declining difficult-to-defend (the opposite of difficult-to-enter) industries. The focus should be on big growth opportunities which present realistic and achievable technological and market goals.

There are several possible ways of moving toward this objective. Firstly, there would appear to be scope for revising incentives to develop overseas markets for promising technologies and products which are already in existence. Evidence from the Ziton case and others suggests that public provision for overseas marketing are unworkable and certainly less attractive than for the development of new products or processes. If anything, the reverse situation would be preferable. Incentives should target those product and process technologies which could credibly succeed on a big scale in large, difficult-to-enter markets. The key would be to avoid supporting companies which already have export market capabilities and experience and those whose products are not sufficiently well-developed to have a realistic chance of competing overseas in difficult-to-enter markets.

Secondly, a complete export market entry and development strategy and business plan should be a pre-requisite to any grant or financial award in support of the development of a new product. It could be argued that the rules are even more stringent, and require prior establishment of overseas marketing and distribution channels as a pre-requisite. This would tend to favour existing exporters, some of which may not be best placed to expand revenues in future. However, it could be made a pre-requisite for any secondary funding. It would seem appropriate in many cases to make research of and visits to potential overseas customers a required initial component of innovation grants. This might serve to alert the bidders to critical aspects of overseas customer needs which might otherwise have been overlooked as well as providing useful initial clues as to what foreign marketing strategy might be most appropriate. In this respect, it may be worth considering some changes to the SPII and Innovation Fund grants. Some SPII awards have gone to companies that have never achieved substantial international success despite years of heavy investment in innovation. It would seem to make more sense, if anything, to assist them in managing the international commercialisation process rather than developing more new products. A substantial proportion of the much larger grants made available through the Innovation Fund go to consortia which are focused on addressing local market needs, have no export strategy and lack any capability to implement an export strategy. The evidence on the management of innovation is not encouraging about the likely economic benefit of such expenditure.

5.3. For broad-based job creation, evaluate public investment in innovation by how well it is embedded in a competitive manufacturing capability

If we are serious about reversing the situation of job losses in lower skill categories, we cannot afford to invest public funds in developing new technologies which are not subsequently manufactured in South Africa. One cannot simply limit public innovation funds to companies with demonstrated competitive manufacturing capabilities as this would disadvantage those wishing to invest in developing their manufacturing capability in future. Where product technology is being developed for which the corresponding manufacturing capabilities do not exist in South Africa, there should be a requirement that proper account is taken of the costs and risks associated with establishing a manufacturing capability. If this may not be feasible, then any funding for product development should be considered cautiously unless a local partner willing to invest in developing the manufacturing capability can be found.

5.4. The company is the primary site of innovation activity

If it is to become sustainable and lead to the development of dynamic capabilities, innovation must ultimately be carried out within one or more companies. No amount of great technologies developed in isolation from real customers, real implementers and real suppliers will lead to the kind of dynamic capabilities which are necessary for sustaining competitiveness in today's turbulent markets.

The innovation process may and often does begin outside the company, for example in public research institutions. There is implicit recognition of this fact in the structuring of government support for innovation such as via the Innovation Fund. Bidders are required to have private sector partners, but in reality this requirement may not always be sufficient as it does not ensure that the private partner is the driving force in the partnership or is wholly committed to the project's commercial success.

5.5. Summary

It is hoped that this will serve as a reminder to decision makers in innovation policy of the importance and difficulty of commercial rather than technical success in innovation projects. Great technology will not solve our employment problems, unless more entrepreneurs, managers and their organisations acquire the necessary skills to be able to enter and compete successfully in difficult-to-enter markets. Ultimately, complex, difficult-to-acquire managerial capabilities are no less important than technological ones for achieving this. Policy should reflect this by seeking to take advantage of the opportunities that exist to improve the export capabilities of companies with advanced technological capabilities and a targeted approach to developing technological capabilities in areas with promising export markets.

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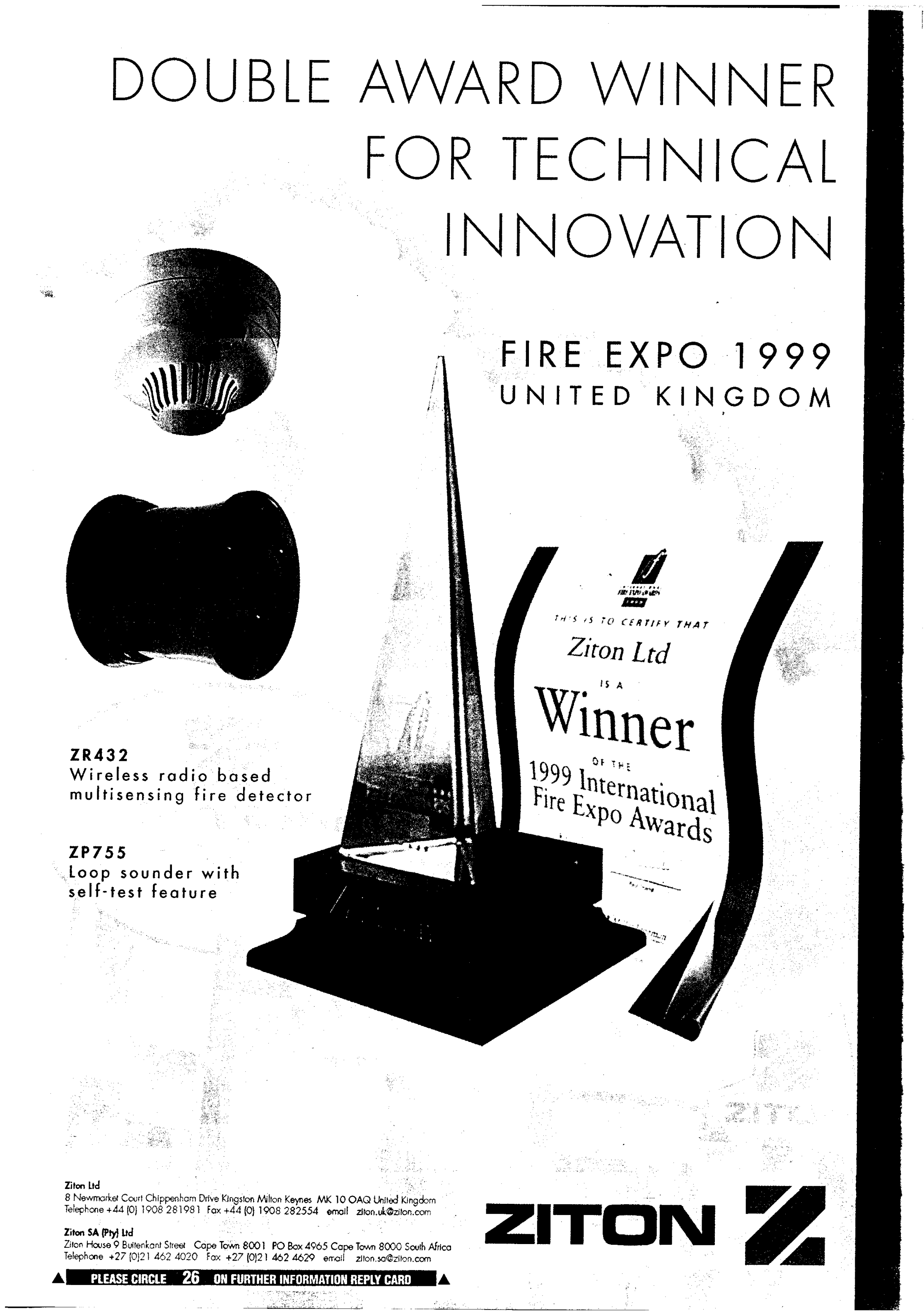
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