TECHNOLOGY MANAGEMENT AS A TOOL FOR GLOBAL COMPETITIVENESS

by

Erwin Bauernschmitt

Mini-Thesis

submitted in partial fulfilment of the requirements for the degree

Magister Ingeneriae in Engineering Management

in the

Faculty of Engineering

at the

Rand Afrikaans University

Supervisor: Prof. L. Pretorius

May 1997

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SUMMARY

As the world is forced to face the evolution of an increasingly dynamic and truly global market environment, it has become imperative for organisations, small and large alike, to embrace more the concept of technology management in order to survive the competitive forces and to establish, maintain and grow in a world market place.

Indeed, the consideration and application of technology management in a holistic perspective not only ensures business survival, but to those who successfully implement the concept awaits the challenge of becoming global market leaders and hence, future prospects of growth. Consideration of this fact in the demanding light of international business, distils the role of technology management as one of the key strategic principles of any organisation. This key role is likely to assume increased importance, with the nature of technology management emphasised on positioning an organisation in a manner which will enable it to derive maximum business advantage over its competitors.

As such, this scouting study therefore aims to briefly explore and discuss the role technology management has to play in the business plan of any organisation. The main output of this overview is the development and presentation of a technology management plan (TMP). The objective of this 8-step management model is to focus on and address the factors which relate to the establishment of a successful organisational presence in a globally competing business environment. The TMP provides an implementation framework which allows the application of technology management in a step-by-step methodology. This plan or framework provides a tool which can be employed in any organisation to retain its market share, as well as to attain the goal of future growth, in order to achieve increased profitability and maximum return on investments. Correct implementation and application of the technology management plan (TMP) will enable an organisation to successfully manage, steer and accomplish the process of technology management. In achieving these aspects within the dynamic market place of today, lies the real key for establishing, maintaining and improving global business competitiveness to a direct market advantage.

Consideration of work undertaken in the field of technology management indicates that various investigations have been performed regarding the aspects, nature and role of technology management. However, less research seems to have been conducted which addresses the development of an integrated framework or methodology whereby a technology management philosophy can be implemented or applied. This initial and exploratory survey constitutes an attempt in that direction and is based on a wide, yet critical overview of related literature.

SAMEVATTING

Die wêreld word tans in 'n toenemende mate geforseer om die ontwikkeling van 'n uiters dinamiese en werklik globale markomgewing te aanvaar. Binne hierdie raamwerk, is dit dus noodsaaklik vir alle organisasies, om hulself volledig te bekwaam aangaande die konsepte van tegnologiebestuur. Deur vertroud te wees met die beginsels van tegnologiebestuur kan organisasies die strawwe kompeterende aanslag op hul posisies in die wêreldmark afweer en selfs hulle markdeelname verder uitbou en versterk.

Die suksesvolle aanwending van tegnologiebestuur vanuit 'n holistiese perspektief verseker nie slegs besigheidsoorlewing nie, maar vir diegene wat die beginsels suksesvol kan implementeer, bestaan daar ook geleenthede en uitdagings om as toekomstige wêreldleiers binne die spesifieke mark te kan ontwikkel. Oorweging van hierdie aspekte in terme van die veeleisende internasionale besigheidswêreld, spel die rol van tegnologiebestuur as een van die sleutel strategiese prinsiepe van elke organisasie duidelik uit. Die beklemtoning van hierdie sleutelrol binne die sakewêreld dui daarop dat dit van toenemende belang is met betrekking tot die rol wat tegnologiebestuur speel in die posisionering van 'n organisasie op so 'n wyse dat dit maksimale besigheidsvoordeel bo die markkompetisie kan verseker.

Hierdie studie ondersoek die rol van tegnologiebestuur binne die konteks van 'n organisasie se besigheidsplan. Die ondersoek lewer as uitset 'n agt-stap bestuurs model wat 'n raamwerk daarstel vir suksesvolle tegnologiebestuur. Die tegnologiebestuursplan spreek die faktore aan wat 'n invloed kan uitoefen op 'n onderneming se suksesvolle teenwoordigheid al dan nie, in die internasionale besigheidsomgewing. Voorts stel die tegnologiebestuursplan 'n raamwerk daar, wat die implementering en aanwending van tegnologie in 'n stapsgewyse metodologie fasiliteer.

Korrekte aanwending van die tegnologiebestuursplan sal 'n organisasie in staat stel om die proses van tegnologiebestuur suksesvol aan te pak en uit te voer. Sodoende word die organisasie se vlak van internasionale kompeterendheid tot 'n direkte markvoordeel aangewend.

CONTENTS

1. INTRODUCTION

The contribution of technology to the level of economic growth and success a country attains, is an important indication of the role technology has to play in creating systems of benefit to mankind. To underline this consideration, it is apt to state that technology enables nations to increase the overall standard of living[16,25,26,37,45,51,55,60,75,90,104,111,117]. The immediate implication of the foregoing is the realisation that an important requirement exists with regard to a process whereby technology can be facilitated and managed in order to achieve the desired level of contribution to national and international welfare.

Technology management constitutes this process which is necessary for the well-being of any societal organisation, whether it operates within a national dimension; whether it is a governmental institution or even a private corporation. The nature of technology management therefore implies that it interfaces with individuals[7,27,31,37], society[37,94,96], as well as the overall environment[65,73,95,122].

Current socio-techno-economic factors of the world dictate that all three types of institutions are being forced to increase their engagement in activities of an international order, leading to multi-firm focus and presence in the world market[70]. This global commercialisation of products and services has created intense business competition[13,15,20,48,49,50,52,53,58,60,61,68,79,87,98,109,117,119,124], whilst at the same time exposing previously unexplored market opportunities[17,63,70,72,93,101,108]. As the globalisation of the world economy progresses, new forms of international co-operation continue to unfold[29,60,62,66,87,99,103].

In addition to the rapid rate of innovation enabling the achievement of great technological advances, the increased globalisation and flow of technology[56] has resulted in the emergence of new world technology players[13,44,47,60,93], able to act as new sources of technology.

This means that a previously limited group of nations or businesses, no longer posses the technological monopoly which, more often than not, formed the backbone of product or service market advantages. Many corporations from traditionally

developed nations now pursue policies which actively seek and enter into trans-national investments, forming multinational groups or ventures in order to facilitate, transfer and exchange technology[18,19,28,34,75,111,117,118] with the aim of establishing technological superiority centres for subsequent commercial exploitation. Such mergers or collaborations harness the positive and synergistic effect of partnership in terms of complementary markets, facilities, resources and business strengths[35,112,118]. These agreements can assist corporations in maintaining their comparative advantage[15] and hence, competitiveness. Implementation of this view allows technology to exhibit an influence much faster than previously possible and also increases the international scope of impact[5]. However, it is evident that inadequate or poor technology management within such a demanding and dynamic business environment, holds the potential to result in a direct lack or underperformance with regard to sustained global competitiveness.

An interesting and noteworthy spin-off resulting from these recent changes in the view of technology, lies in the fact that undeveloped countries, now acting as technology recipients in multinational business agreements, are rapidly able to develop a technological capability[44,70]. This facet of change within the role technology has to play in the global economy may yet prove to be one of the key building blocks for the industrialisation, economic improvement and overall upliftment of undeveloped or developing[93] countries.

2. DEFINITIONS

2.1 Technology

Technology can be described as any organised body of knowledge which can be applied across the entire spectrum of human endeavour. Technology is a human creation[55]; in fact it is the oldest of human creations (e.g. method of fire-making, development of the wheel), which in turn has the potential to enlarge mankind's capability. In essence, technology can be described as the totality of all goods, tools, methods and services, that are available to mankind

to live and sustain life[9]. Technology enables humans to increase the control over their surrounding environment[45]. More specifically, technology entails all products and services resulting from human knowledge, capability and creativity[67]. It can be manifested in a number of forms, some of which include[71]: machinery, appliances, processes, instruments, apparatus, materials, methods and procedures.

Historically, the word 'technology' is derived from the Greek word: 'techno', which refers to the practice of a systematic skill, science or treatment[22]. In a more modern context, technology can also be defined as the foundation on which innovation is built[26,39,90]. It has been described[37,39,117] as the transfer function between pure science and invention. Innovation, in this context, can be described as that portion of invention which translates into marketable products or services[35,37,39]. The process of technological innovation is also referred to as the creation of wealth[25] and the enhancement of human effort through the application of technology.

2.2 Management

The word 'management' is derived from the Latin word 'manus' and later from the Italian word 'maneggiare', which refers to the act, art or manner of controlling[22].

In a more modern context, it can specifically be described as the professional administration of business activities[36], where business activities include all aspects that relate to an organisation and its operation of a business. To illustrate this concept, consider the following. Management's role[84], throughout an organisation, is to establish common objectives, organise, plan, motivate, measure performance, and to develop, train and equip its people. The following figure[80] summarises the functions of management.

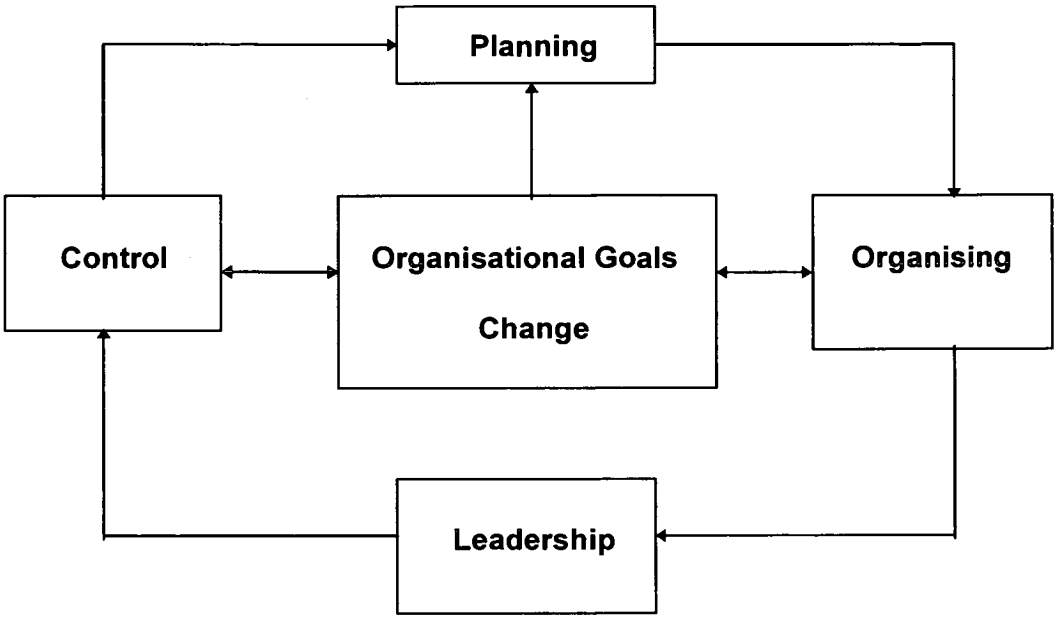

Figure 1 : Managerial Functions[80]

2.3 Technology Management

Technology management can be defined as the process whereby organisations identify, access and employ the existing and potential sources of technology on an international basis, viewed in the perspective of ensuring continued competitive advantage[68], profit growth and enhanced shareholder value through achievement of results which will facilitate optimum customer[124] and community benefits[51,94,96]. This implies that technology is utilised and controlled (i.e. managed) in an efficient manner[41,88], at a suitable time and in conjunction with furthering the business aims and goals[5,24,25,26,33,45,49,55,70,75,102,112,120].

2.4 Competitiveness

Competitiveness, from a business perspective[53,55,70], can be defined as a nation, organisation or corporation's ability to create, produce, distribute and maintain services or products in an international trade, whilst earning rising

returns on the application of its resources. This implies that competitiveness involves a process of value addition with respect to the resources of any institution, in order to achieve enhanced living standards and/or profits[70]. The word competitiveness is derived from the Latin word: 'competere', which refers to the concept of seeking or entering into rivalry[22].

3. THE CONCEPT OF TECHNOLOGY MANAGEMENT

The fact that modern age society is increasingly dependent upon the application of technological innovations[16,53,75] in order to create useful systems, be it products or services; as well as the rapid pace of this technological change[5,20,28,49], inevitably generates enormous challenges with respect to the proper handling of technology as an useful resource. As such, technology interacts with every aspect of an institution[31,37,122] and this makes the understanding of technology related aspects and processes imperative. The rapid development of technology has lead to many advanced, critical and looming technologies[64] being identified and employed as sources of competitive strength within the business environment. It is this technology management aspect which determines, by successful application thereof or not, whether companies obtain and maintain the competitive edge in the world[70]. In order to achieve this, a corporation must be timeously aware of and able to employ technological discoveries and innovations, in conjunction with optimal resource and knowledge-base utilisation.

An illustration of the importance of correct technology utilisation in terms of the competitive status of a business, can be found in an example of product performance differentiation[64]. The introduction of executive automobiles with anti-lock braking and personal safety systems(ABPSS) and improved ergonomical designs[82,105], enabled the pioneering manufacturers to obtain a competitive edge over its rivals. This is an example of the application of the concept of continuous improvement processes[32] within the automotive industry. Another example of good technological application can be found in Land Rover's recent consolidation of the local (SA) four-by-four market, with its re-launch of advanced engine power (BMW) combined with technological safety aspects for on and off-road handling, e.g. anti-impact features, as

well as extensive real-time vehicle testing. In addition, technological applications in terms of ergonomical design considerations[105] for improved driving comfort, in conjunction with the above, has resulted in the vehicle manufacturer securing a second position in national (SA) 4x4 sales. This is an improvement up from 7th position for the previous year (1995/1996), with the SA market for Land Rover strongly in 3rd position world-wide for the company[30]. Toyota SA also geared for increased international competition in 1996[23], with the investment in a high-technology car spray colour booth. This new era of paint technology is envisaged to lead Toyota towards more effective international competition. These aspects of technology management clearly illustrate the potential benefit in terms of profit growth and market capitalisation, which can result due to the correct utilisation and application of technology. Such a holistic approach or philosophy towards technology management[33,88,102] promotes the final objective, namely increased product or service quality and hence, a higher level of competitiveness.

The role of technology in the 20th century as a contributor to economic growth and international development of a country is well established and undisputed[75,111,120]. In addition, technology plays a major role in the productivity and international competitiveness of a nation[25,47]. The 1997 World Competitiveness Report (Preliminary-March 1997)[47] clearly indicates a correlation between the level of national technological competence and that country's economic performance or ability in terms of the competitiveness index. It is clear that those countries boasting a more developed state and wider application of technology, as well as an awareness of the importance of technology and its management (i.e. policy) with regard to economic well-being and competitiveness[26]; typically the top ten or twenty nations in the chart and table presented hereunder; are outperforming other nations economically, as well as in terms of competitiveness. An interesting link between global competitiveness and economic status can be derived from the top performing countries, in that the countries with highest competitiveness (March 1997) scores (e.g. USA, Singapore, Japan etc.) also hold most of the top Fortune 500 (1996) companies (per nation), as well as top profit growth rankings[20]. Table I and Figure 2 display the world competitiveness data for March 1997 (preliminary report)[47].

TABLE I : 1997 COMPETITIVENESS INDEX SCORE AND GLOBAL RANKING[47]

Country	Score	1997 Ranking
USA	379.25	1.
Singapore	342.53	2.
Hong Kong	298.23	3.
Finland	294.97	4.
Netherlands	284.79	5.
Norway	284.78	6.
Denmark	284.75	7.
Switzerland	284.08	8.
Canada	280.41	9.
New Zealand	275.24	10.
Japan	273.01	11.
U.K.	268.61	12.
Luxembourg	266.58	13.
Germany	257.63	14.
Ireland	256.07	15.
Malaysia	248.79	16.
Australia	245.47	17.
Sweden	245.39	18.
Austria	242.04	19.
France	240.27	20.
Iceland	229.60	21.
Chile	226.88	22.
Belgium	224.12	23.
Taiwan	217.84	24.
Spain	216.05	25.
Israel	205.36	26.
China	184.23	27.
Thailand	170.77	28.
Argentina	169.43	29.
Philippines	165.96	30.
Korea	163.84	31.
Portugal	157.14	32.
Brazil	156.75	33.
Turkey	153.25	34.
Italy	152.72	35.
Czech Republic	145.42	36.
Hungary	140.18	37.
Greece	135.67	38.
Indonesia	132.49	39.
Mexico	131.58	40.
India	112.20	41.
Colombia	103.51	42.
Venezuela	102.33	43.
Poland	94.97	44.
South Africa	94.54	45.
Russia	18.89	46.

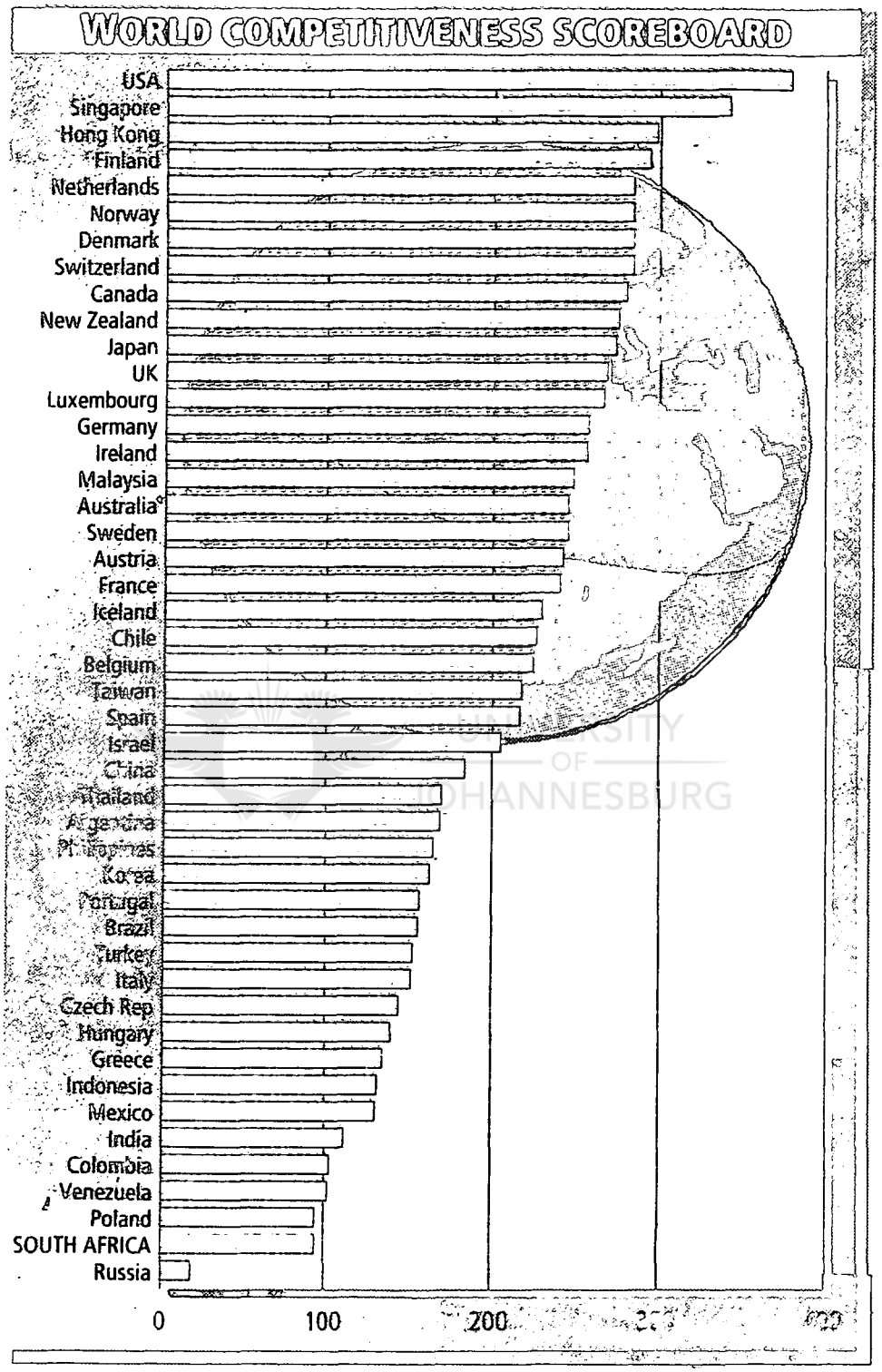

Figure 2 : 1997 Global Competitiveness Score[47,58]

The World Competitiveness Report is published annually by IMD Management and Business School, Lausanne(Switzerland)[47] and compares the competitiveness level of selected countries. The comparison is based on 381 criteria, which are grouped in eight main categories(as presented in Table II) and form the basis of the competitiveness index score of each country. This clearly illustrates the correlation between a nation's level of global competitiveness and the economic well-being of that country. On the other hand, countries associated with lower levels of technological competence, generally report to a weaker national economy status.

Sadly, South Africa ranks second to last for the countries presented in Table I and Figure 2, and it appears as if South Africa has not yet embarked on the road to improvement[45,58]. Table II presents various factors of competitiveness and summarises South Africa's under-performance[47,58]. The Science and Technology factor lies at a ranking of 37 out of 46 surveyed economics and has shown a marked decrease in ranking (i.e. competitiveness) since 1993.

TABLE II : SOUTH AFRICAN FACTORS OF COMPETITIVENESS[47,58]

Factor	Yearly Ranking (Amongst 46 Economies)				
	1993	1994	1995	1996	1997
Government	43	38	35	37	35
People	46	46	46	46	46
Finance	23	26	27	31	33
Domestic Economy	41	42	42	44	39
Infrastructure	32	37	30	32	28
Internationalisation	32	35	38	39	44
Management	32	35	38	40	43
Science & Technology	29	28	31	34	37

The positive effect of technology on Italian small and medium-scale businesses, where the level of technological innovation in companies with fewer than one hundred employees hardly lags behind that of the biggest firms, has been attributed as a key factor[2,63,101] in the continued growth of these manufacturers. One of the primary

areas of technological utilisation in this country lies in the application of information age technology for the production of traditional products[2,101]. Indeed, the Italian industry has developed a new strength in the thousands of sophisticated small to medium sized companies. It is estimated that these technologically adapted factories account for one-quarter of Italy's $240 billion per annum export figure[2] and are largely exports of manufactured products from companies with only 11 to 100 employees[2].

The Italian competitiveness can thus clearly be linked to the level of technological competence existing within the country. This is especially true for the manufacturing and design competence of a nation[46,76,104]. The following figure(1994 data)[25] illustrates the correlation between the technological competence of a country and its domestic economic performance(i.e. an indirect indication of the country's level of competitiveness).

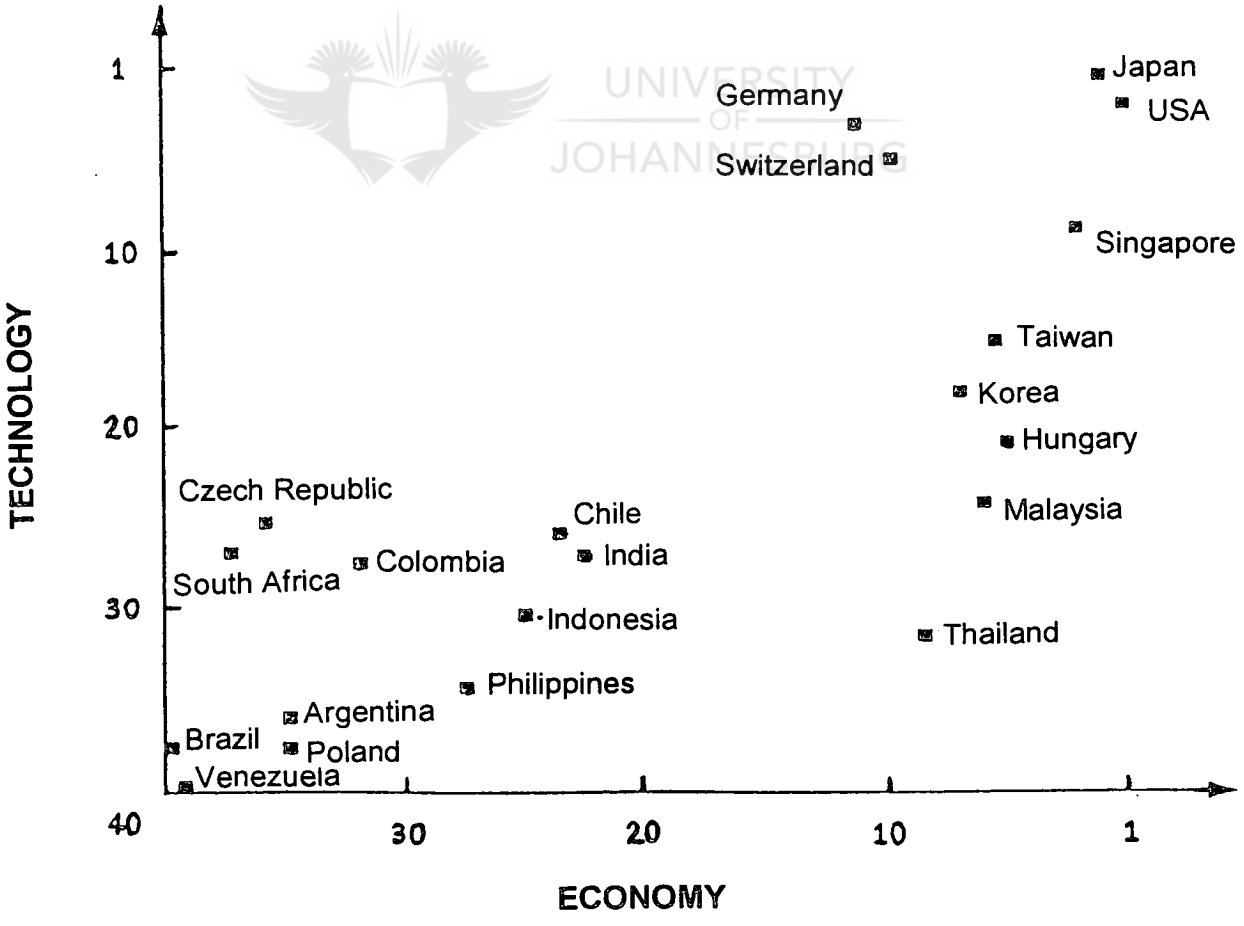

Figure 3 : The relationship between technological competence and economic performance of a country[25]

During periods of change, entrepreneurs increasingly reap good financial harvests from their own businesses. The application of high-technology to small scale business is no exception[56] and is gaining momentum[63,101]. The largest area of high-tech application is in the information, computer and electronic business environments[2,51,79,85,86,91,123] and even there, company owners employ the principles of technology management, albeit in less formal manners than in larger corporations[56,63,101].

The preceding underlines the importance of apt technology management in order to attain not only national, but also international economic success and future prosperity. The General Electric(GE) success story is another[54,59] example which illustrates how technology can be utilised to become a global market leader. However, this requires[16,19,24,25,27,28,45,55,59,87,90,102] efficient technology management. The proper conduct of technology management is achieved through an interdisciplinary interaction of core areas or capabilities[75]. These areas interact to produce the broad parameters for the field within which technology management can be defined. The management area includes financial and human elements. Figure 4 demonstrates this interaction area graphically.

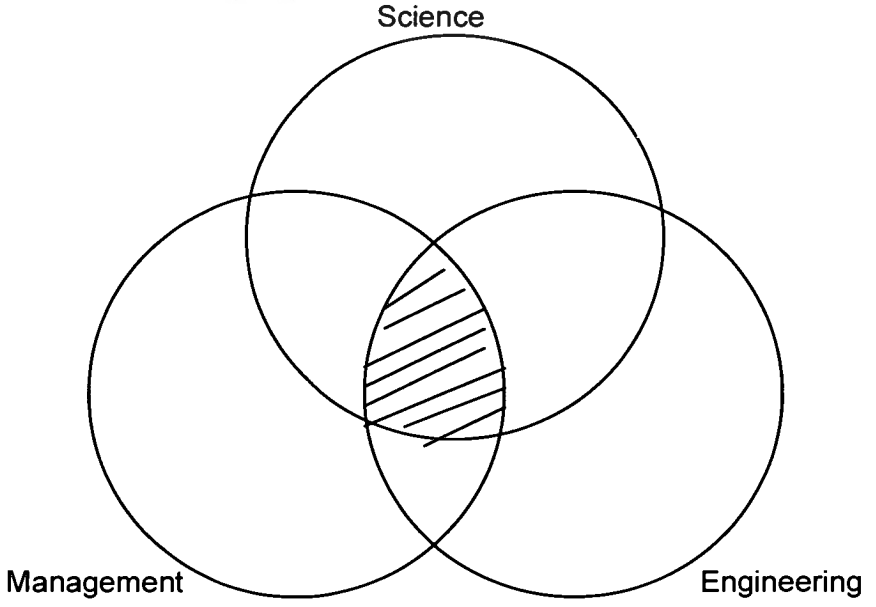

Figure 4 : The Field of Technology Management

The successful achievement of such an interdisciplinary approach[64] depends not only on the existence of a technological infrastructure within the organisational framework, but also on the suitability and availability of this infrastructure. Correct technological planning will therefore ensure proper integration of foundation and emerging[64] technologies. This type of planning should always be performed in the light of and included in the overall corporate strategic plan[24,33,45,107,112], as technology management implies the consideration, selection, and if necessary, the development, followed by the implementation of varying suitable technological alternatives or options in order to satisfy and promote the overall corporate business strategy. Just as strategic analysis and the subsequent development of a strategic plan is carried out against the background of the corporate culture[5,6,24,33,40,41,59,70,75,87,88,102,107,117,122], the history of the company and the aspirations of the company leadership[37,112], the approach towards technology management should also take these company-specific factors[119] into consideration.

Only in this manner can the overall contribution of technology claim its rightful place in terms of benefits derived and those potentially available to the organisation. An analysis or need determination must therefore always compare the proposed technology management framework of a particular institution, against not only the needs of the current market environment, but must also review the framework periodically, so as to update it and to facilitate any specific new market changes or forces that have arisen. The technology management framework[75] must thus also attempt to take the current and future actions of market competitors into account[17,35,53,61,72,109], predominantly addressed in a business direction overview and analysis step. This implies that a strategic management approach is required[41]. Only then does technology management promote the competitive corporate strategy, namely by enabling the institution to achieve business profit in either the services or products offered.

Viewed in this light, it becomes evident that the technology strategy must incorporate and relate to the marketing and overall business operations strategies. It does not function in isolation. This offers the possibility to develop the technological framework with regard to, not only the short and medium market focus points, but also to include

long-range technological aspects, such as the development of technology for long-term strategic applications(e.g. the development of replacement technologies). This strategy-driven or orientated approach to technology management[112] can be illustrated as shown in Figure 5[adapted 70,112].

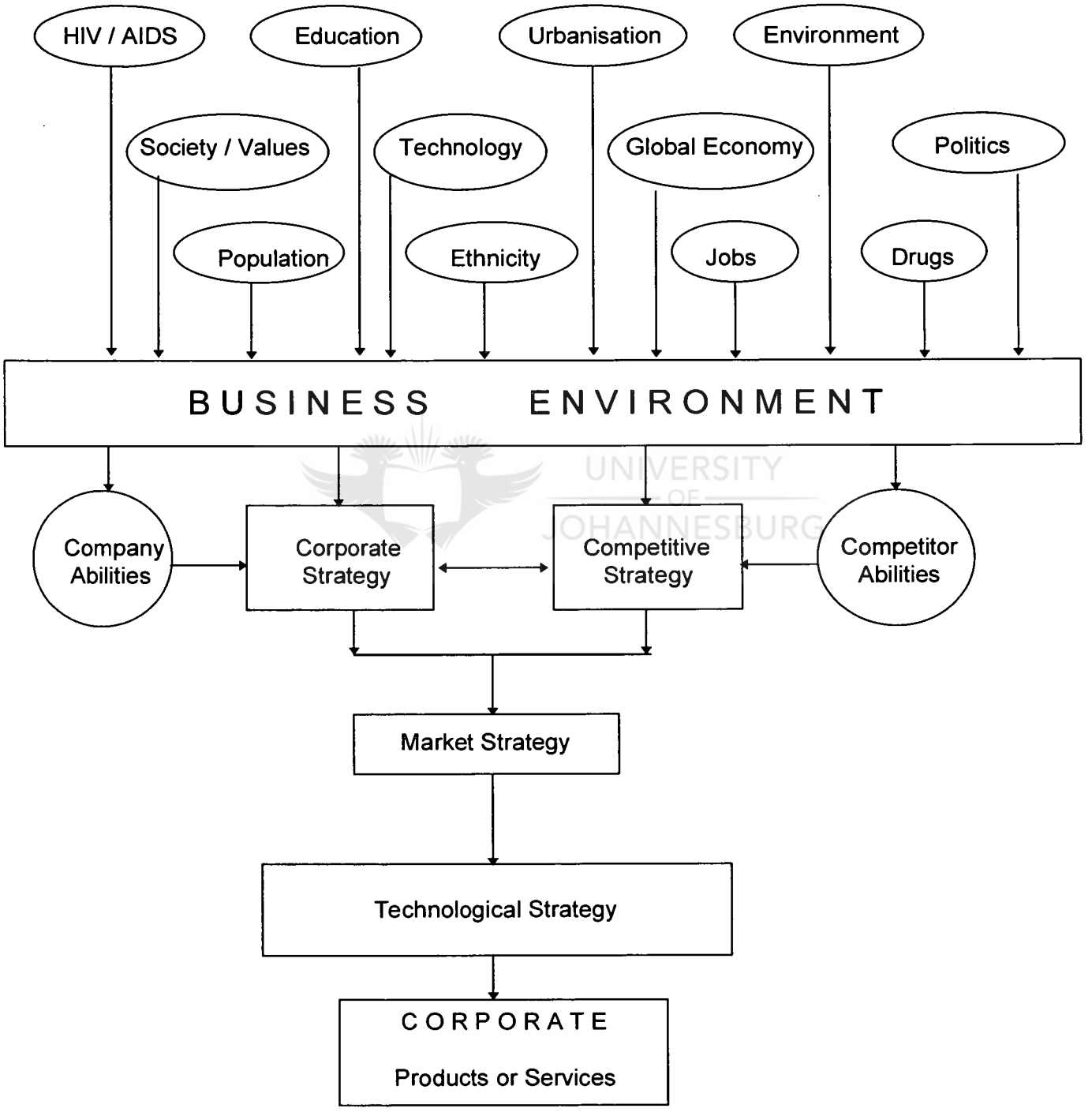

Figure 5 : The strategy-driven technology management approach[adapted 70,112]

In contrast to this approach, it is important to note that, although technology plays a vital role in business success, the 'correct' application of technology and its subsequent development is indeed mostly an uncertain facet, with no direct indication of the manner in which technology will assist in meeting the corporate objectives beforehand. This view has lead to the formation of a technology-driven approach[112], which aims to exploit the uncertain status of technology in order to facilitate and foster useful innovation. This approach utilises a flow of technological possibilities from the bottom of a corporation upwards, whereby the framework focuses on the application of technological possibilities to matching corporate business requirements. This bottom-up technology management framework differs from the strategy-driven technology management framework mainly in that the latter employs technology as a supportive function, with application flow thereof from the top downwards, whilst the technology-driven framework offers a method whereby corporate resources[27,28,37] are assigned to and assist in the deployment and development of technology; with the ultimate aim being continued technological innovation for commercial benefit. Figure 6 illustrates the concept of a bottom-up approach towards developing a technology management framework.

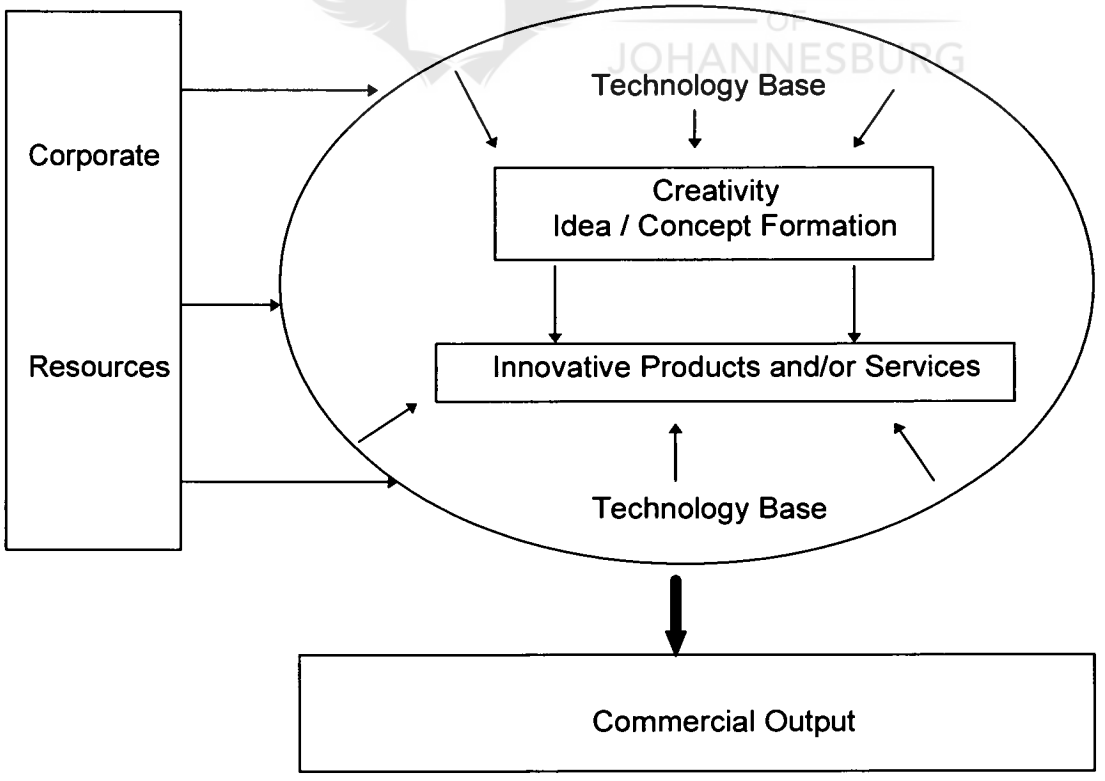

Figure 6 : Framework for fostering continued technological innovation: bottom-up approach

It is important to realise that the modern business environment[17,29,45,48,53,95] comprises of many complex and interdependent variables or factors, which can either be regarded as potential problem areas/threats or opportunities[70], depending from which perspective these aspects are viewed. However, the choice of business action will in turn, depend on the position, and hence the perspective, from which the global challenges were assessed. It is thus quite possible for different, or even the same business, to view aspects, e.g. environmental influences, from differing perspectives and consequently to react or plan completely different to the same factor. In addition, a business might find factors which posed threats in the near past, to present excellent opportunities shortly thereafter, due to the dynamics of the global environment[70,95]. This obviously translates to the marketplace. A periodic assessment should thus be part of the on-going corporate business environment awareness drive.

The fact that technology management is a relatively new and strongly developing field[55], does not imply that the concept of technology and its utilisation is new. Rather, the concept of technology dates back right to the start of mankind. A good example is to consider for a moment, the method of lighting a fire by the use of two wooden sticks[25]. This was indeed a very important technological aspect during those early days, which not only influenced the level of further technological development (due to the use of fire and heat), but also strongly interacted with every aspect of human experience and the social progress of early man. As mentioned before, technology is one of the oldest human creations and can definitely be regarded as a considerable role-playing factor in terms of the changes in human history.

The influence of technology development and the realisation of its potential importance, can be illustrated by referring to the role of technology and related technological changes during the industrial revolution in the early eighteen hundreds. The result of such vast technological development was the establishment of various technology-centred businesses[25]. In other words, the business nature is purely technology-based with regard to the product or service rendered.

In the modern age, the pace of technological development has been increasing, whilst the relative importance of technology has been much larger than before. These two aspects have, upon their combination, resulted in the fact that the underlying technology of technology-centred businesses is no longer a constant parameter[41,79,120,123]. In addition, immediate acceptance, application and in some instances even awareness of available technology, has been limited. Figure 7 illustrates the resulting technology gap between available and employed technology[41].

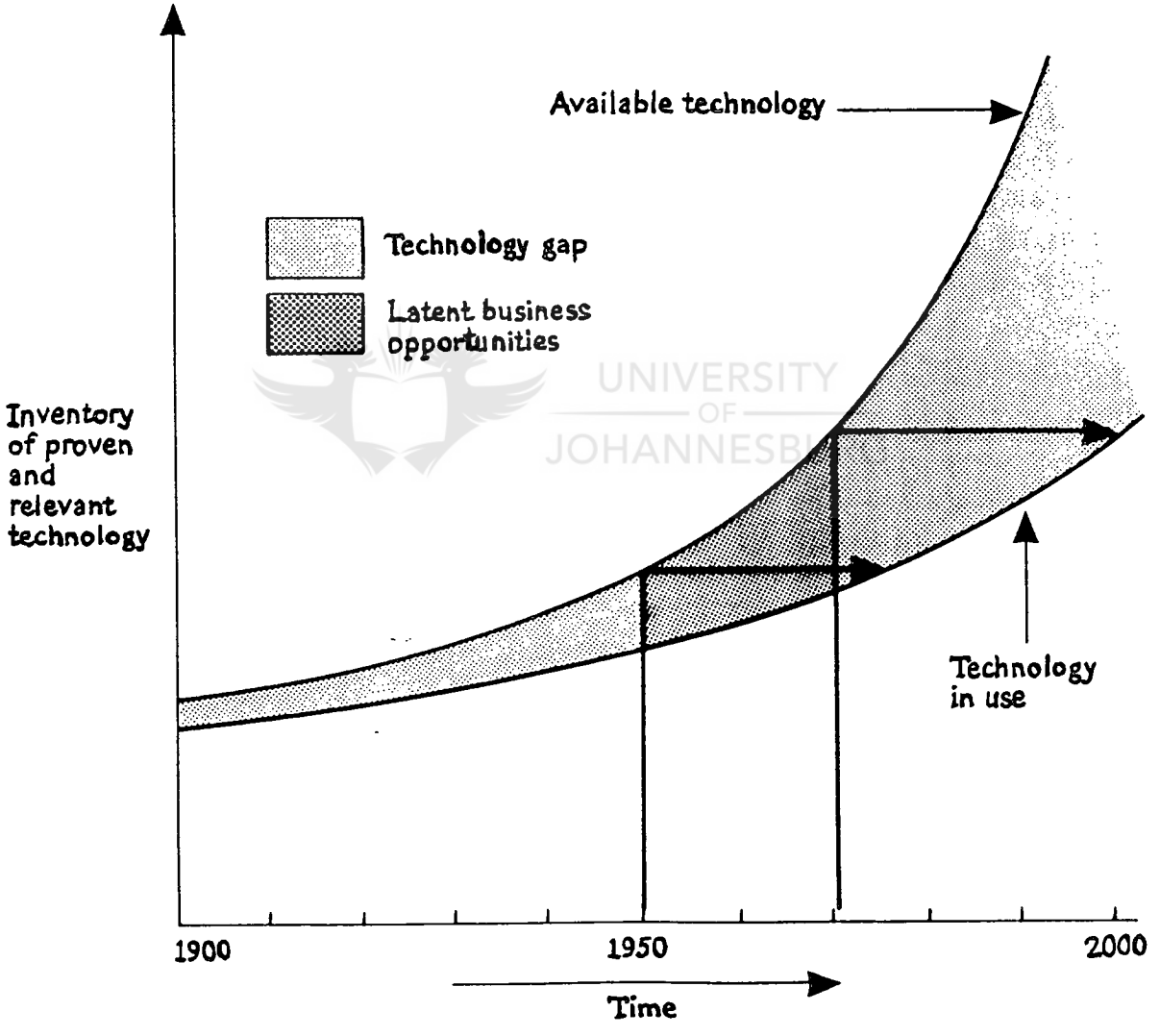

Figure 7 : Schematic representation of the technology gap[41]

This holds great implications for industry competitiveness as a function of technological change. A typical example of this tendency is the loss of US competitiveness[16,29,55,75] in international markets to Far East competitors after the late 1960's. This was mainly due to a more successful technology management programme being implemented, very importantly, within a short period of time[49,70,87], by Pacific Rim(South-East Asian and Japanese) industries[13,44,60,75,79,93,98,99,108]. These countries realised the impact of technological change on competitiveness and re-aligned their technologically-based industries with new or emerging technological competencies and capabilities, thereby directly affecting their global competitiveness positively. This shift in technology philosophy resulted in large losses in US trade which enabled Asian competitors to gain a strong foothold in the world markets. The starting point and tool for such high-impact drives can in no way be separated from the need for proper technology management. Table III summarises the most important reasons for the US losing its previously established competitive advantage in the international market place[55,75].

TABLE III : SUMMARY OF REASONS WHICH LEAD TO US COMPETITIVENESS DROP DURING LATE 1960's[55, adapted 75]

1. Inadequate technology management by executives
2. Insufficient research and development
3. Distortion of capital flows due to improper tax and regulatory policies
4. Resistance to technological progress from labour unions
5. Unfair trade policies
6. Inferior education systems(especially concerning tertiary education of technology managers[56])
7. Thwarted progress as a result of too stringent governmental controls
8. Lack of employer incentives to improve innovation levels amongst employees and to enhance technological applications

From the reasons presented in Table III, the need for technology management is highlighted by the fact that technology is the key to continued successful long-term performance. Indeed, technology propels the economy forward. This necessitates an insight and understanding of technology. Such a technology philosophy

review[88,102,107], with its focus on the topic of competitiveness, would typically address factors[5,55] such as: Innovation, Entrepreneurship, Research and Development Funding, Manufacturing Technology Development, Technology Transfer, Essential Technologies and the Socio-Human aspects of technology. These include considerations such as education[25,97], retraining[50,61,68,81], culture[7,15,37,52,75,87,94,122], human[17,27,31,96,121] and ergonomic[82,105] compatibility with respect to emerging technologies and their envisaged implementation. Only by including all relevant factors, only some of which are mentioned above, will the corporation or nation be able to produce a reliable and adequate technology management policy, which will enable the corporation or business competitor to practice technology management successfully within the international market.

Failure to devise, construct and implement suitable technology arrangement practises can normally be identified by specific symptoms and factors[adapted 75]. Figure 8 presents these symptoms and factors graphically.

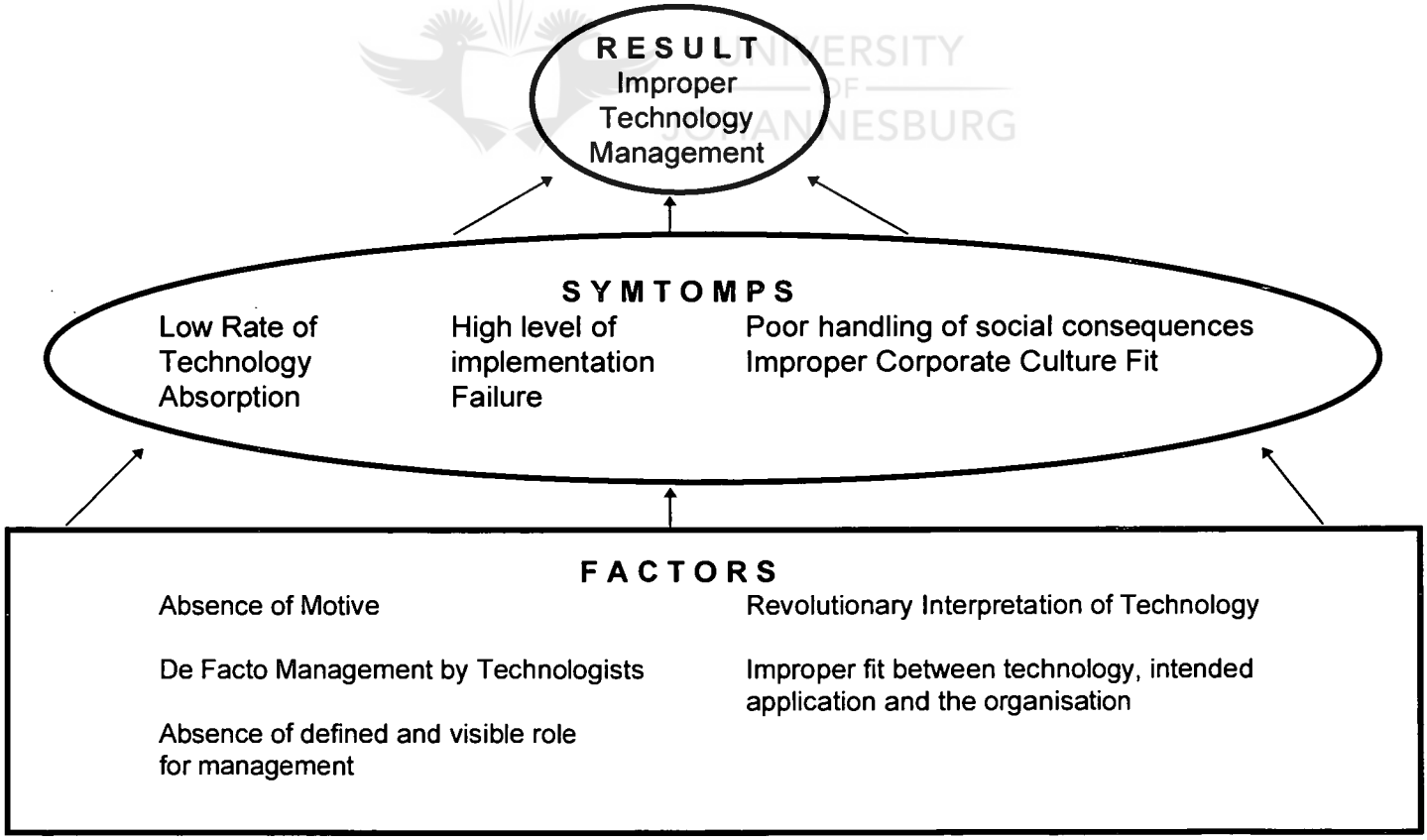

Figure 8 : Symptoms and Factors contributing to improper technology management

It is clear from the preceding that a reactive business response[37,75] to a competitor's successful technology management approach, presents no solution. Rather, proactive innovation and creativity[37,70,75,109] form the key elements to successful technological utilisation and commercialisation thereof.

One of the important realisations concerning technology management is the fact that technology should be considered, treated, controlled and utilised as a resource[51,88,102]. Indeed, the management of technology as a key resource must form part of the business operating plan, as technology is but one aspect which can be managed to gain a competitive advantage. Other functional areas[64,80] in which business competence is required in order to achieve market presence, includes:

- Marketing
- Sales
- Production/Manufacturing
- Finance
- Operations (Facilities, Information)
- Personnel

Technology should thus be regarded as the seventh addition to this resource item list, as it not only exhibits the potential to be prominent in the production or manufacturing key area (as has traditionally[76,79] been the case), but technology manifests itself as a tool which is capable of affecting and improving all the other six functions.

As an example, the flow, storage and capability of information processing has greatly advanced in recent years due to the impact of technology[83,123]. The effect of this improvement has greatly aided the process of business decision making and the concept of information technology(IT)[85,91] now forms an integral part of the modern business age(e.g. MIS).

Figure 9 illustrates the concept of technology as a key resource.

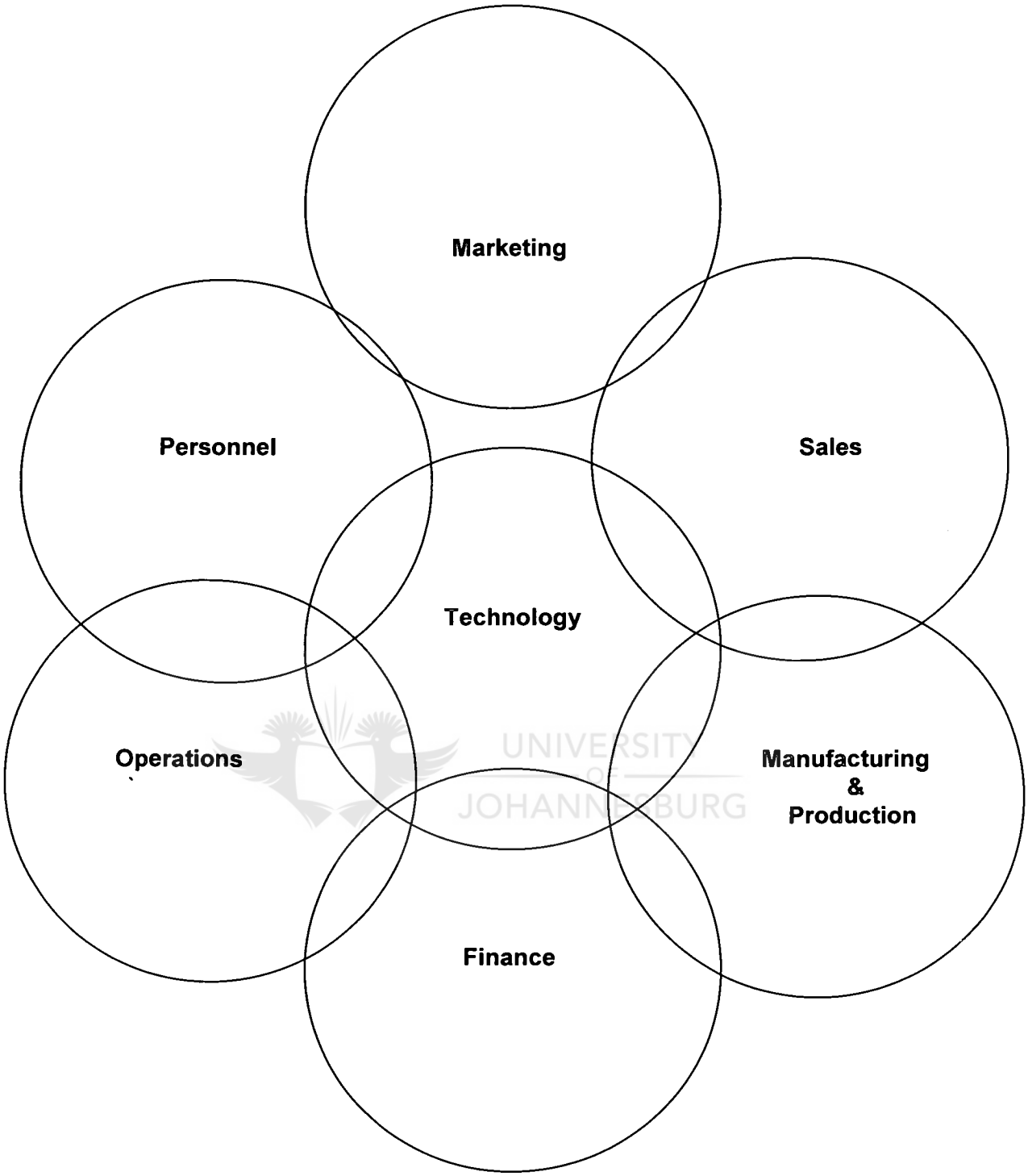

Figure 9 : Technology as a key resource

The role of technology as a resource is thus to be utilised in manners which generate, sustain or improve products and services which will ultimately further profitability. This means that technology management must include parameters[25] such as:

resource-analysis, forecasting and estimation, technology research and development, as well as technology acquisition and transfer[118].

The main growth areas relating to future technology development and potential technology sources are likely to be of the following types[26,45,86]:

- biotechnology
- materials-technology
- information technology (specifically micro-electronics, computers, robotics and communications)
- energy technology

The development of new technological capabilities in these fields will undoubtedly lead to possibilities in terms of new applications in both areas of product and service, as well as in processing or manufacturing environments. The question of where new technology is employed, depends on its function within the application. Corporate applications of technology can normally[112] be divided into four main groups.

- The application of technology to maintain a current product or service line[64,112] utilises mostly incremental technological improvements in order to maintain and extend the product life of existing products or services on offer. This type of application draws mainly on an existing technological knowledge base[112] within the corporation and therefore it is vital that the technology knowledge must continually be identified, evaluated, selected and adopted to or transferred into the firm.

- The application of technology to develop non-radical new products or services[112] as current products/services reach the final phase of their commercial cycle, utilises latest technology, but not necessarily new or untried technology to create new designs which are earmarked to enter the same (or even a slightly different) market segment.

- The application of technology to develop radical, new products or services[112], can mostly be associated with the emergence of a new technology or an important improvement in an existing technology. This type of technology application provides opportunities for corporations who harness the technology[109]. However, those corporations utilising the 'old' technology, and who might be replaced in the use thereof by the 'new' technology, perceive the emergence of new and untried technology as a threat to their market share[109] or dominance. Timing[107,117], i.e. when does the new technology become commercially competitive, requires careful consideration.

- Application of technology to improve and develop manufacturing processes[64,112] in order to devise new or improved methods of production. Aspects which receive most attention will concentrate on issues such as process cost reduction, process efficiency and quality improvements[46,76]. An emerging technological consideration is the aspect of process flexibility development[57] in terms of production quantities, types, capacity and design responsiveness. These factors relate to market dynamics and form complex interactions[17,57].

The classification of technology in terms of the competitive status thereof, can be accounted for by three categories[64] :

- Foundation technologies[64,118] are normally well-established and employed across a broad range of products or services. Most other market competitors[5,17,19,35] have acquired the same level of competence, awareness and use of the foundation technologies.

- Critical technologies are usually still developing within their specific application field or niché and are consequently applied to specific product or service use[35,64,118]. These technologies have not yet been totally accepted or fully introduced into their potential application market (which can be much wider than their original or niché areas of application). Critical technologies subsequently pose both opportunities(those who accept it early on) and threats(those who are not willing to accept it initially) to the market

place[37,49,61,68,70,80,86,92,109,112]. The successful employment of this type of technology offers a good chance for many opportunities and advantages over competitors, as the level of competence and the use of these critical technologies differ vastly between various competitors.

- Looming technologies are mostly uncertain and so-called embryonic[64] technologies with regard to their possible area of application, as well as the potential impact thereof on the market place. Typically, looming technologies either develop into critical technologies or it is established that the application thereof is definitely limited to the current market. Such a recognition generally results in the looming technology or innovation[37] being 'shelved' in undeveloped status and discarded for the time being. As the development potential of a looming technology is depleted, the number of applications increase (less uncertainty prevails). The same trend holds for the change-over of a technology from critical to foundation status[64]. Figure 10 illustrates this developmental path of technology in terms of its competitiveness status and is referred to as the life cycle of a technology[10,28,64].

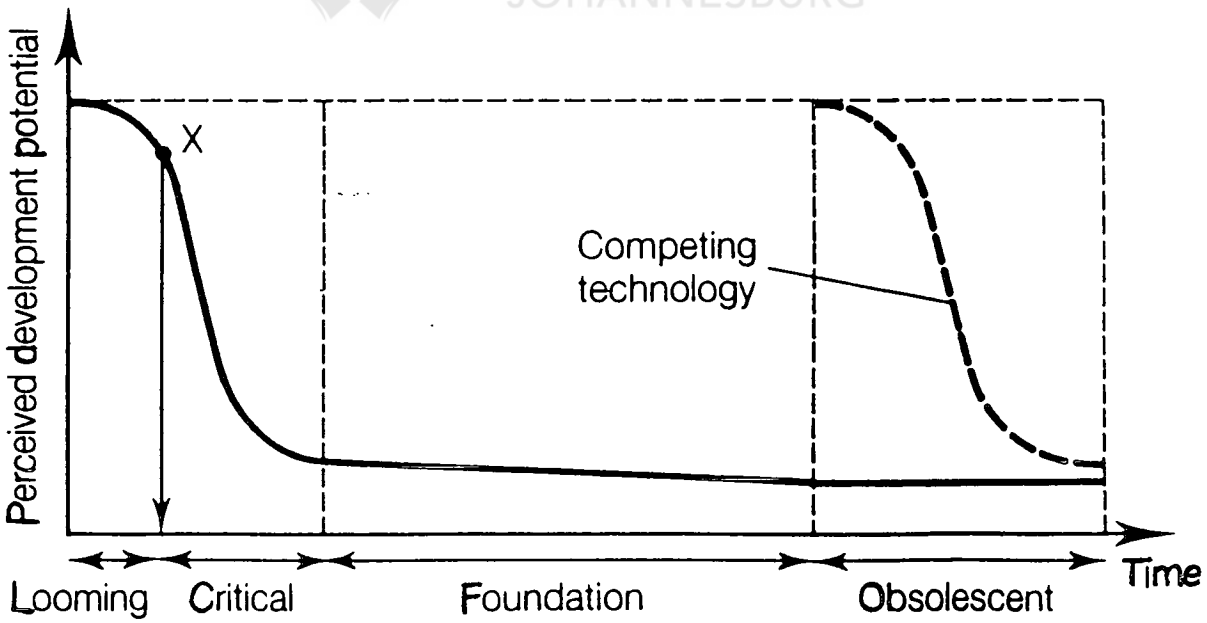

Figure 10 : The life cycle of technology[64]

Figure 11 illustrates the overall application of a technology as a function of time[45,112] if considered within the framework of a systems concept[10].

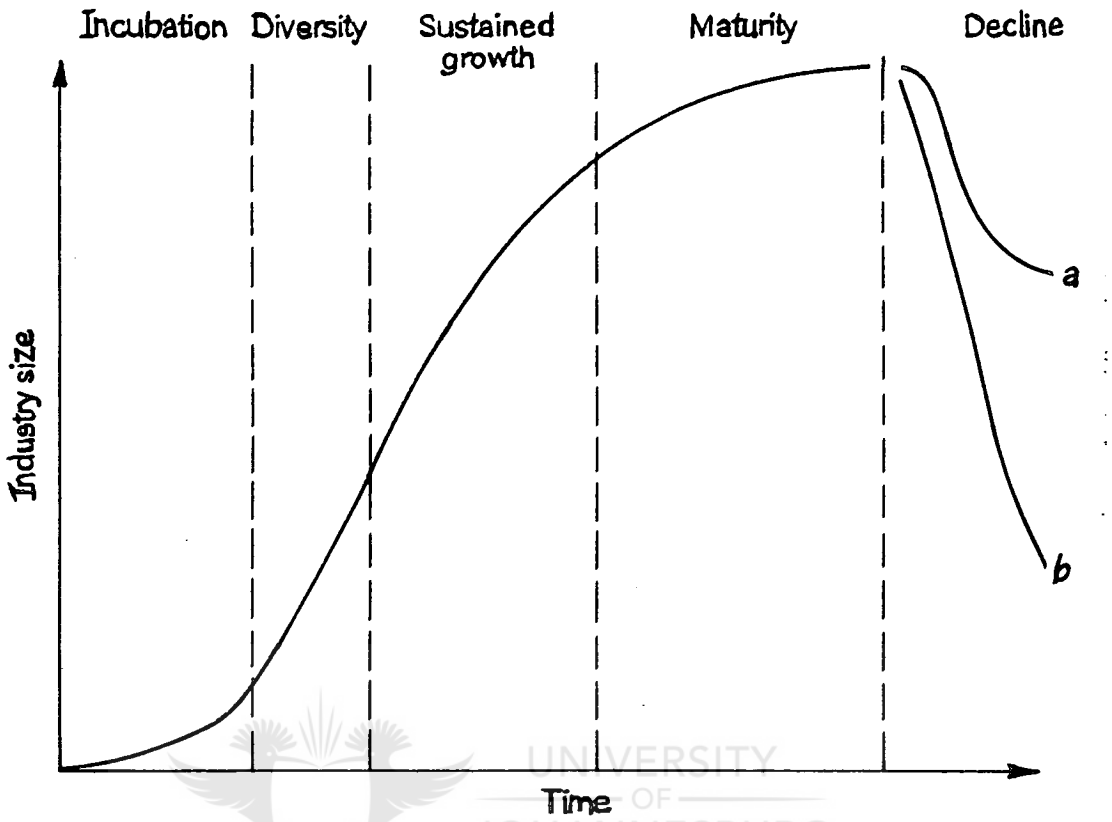

Figure 11 : Technology application cycle[Adapted 112]

a) Slow decline in applications due to the influence of sustaining technological improvement in product or service, thus increasing the market life.

b) Fast decline in applications due to the influence of a new technology application emerging within the same market sphere.

The concept of technology management has been found to be established, with definite requirements existing for the proper management of technology as a resource available to any business or corporation resident in the global arena of commerce. In order to facilitate and outline the required management of technology, a plan or model was developed. This model is based on the flow of a process and will subsequently be presented and discussed.

4. THE TECHNOLOGY MANAGEMENT PLAN (TMP)

The Technology Management Plan (TMP) constitutes a methodological framework or model, presented in the form of a process plan, which defines and assists in the implementation and application of all aspects of technology utilisation. The TMP is intended as a tool whereby actual technology management can be carried out in a clear, step-by-step manner.

The TMP comprises of eight different functional steps and can be considered as a special form of a systems engineering management plan (SEMP)[10] which addresses functional business aspects instead of hard-core engineering functions. Nevertheless, the TMP relates previously individually defined activities in a specific order and thereby binds the functional activities with each other and to technology in the overall context. The result is an integrated plan which produces as its output, a systematic, yet holistic approach in the form of a process outline for technology management.

Considering the TMP in the light of a holistic technology management philosophy, it is important to take note of the following aspects:

- The TMP is intended to be employed as a tool, which aids technology management and allows it to be carried out and performed in an easy, transparent and understandable manner.

- As is the case for any other plan or framework, the TMP requires regular or periodic updating in order to keep the factual input up to date and accurate. A plan is only as good as its last update and the dynamic marketplace dictates that this aspect be regarded on an on-going basis.

- As the outline of the TMP essentially describes a process, the use thereof can be regarded as a continuous process in itself, with scope for iterative repeats thereof on a continuous basis. This means that the TMP can be performed within the broad context of a technology strategy and can play an interactive

role between the business environment and the technology strategy. Just as the technology strategy can impart on the overall direction of the TMP, so can the TMP provide output, in terms of new information, to the technology strategy. The TMP thus aims to provide a 'mixed' approach between the strategy-driven[5,26,28,33,41,59,111,112,118,119,120] and technology-driven approaches[5,26,37,41,55,75,88,90,102,107,119,120] towards technology management. The output of the TMP can therefore be used to update and indeed, even to redirect specific aspects of the overall technology strategy. It is this interaction, rather than a classical[88,102,112] one-way flow from the technology strategy to the TMP (to conduct actual technology management), that aims to assure an improved system responsiveness and therefore provides the organisation with much needed flexibility in terms of navigating the modern business environment.

The TMP comprises of 8 functional steps:

- Business Direction Evaluation (BDE)
- Technology Requirement Analysis (TRA)
- Technology Survey
- Technology Assessment and Selection (TAS)
- Technology Acquisition, Transfer and/or Development (TAT & D)
- Technology Deployment
- Technology Forecasting
- Required Resource Identification

The concept of the Technology Management Plan (TMP) can be illustrated graphically by the flow diagram presented in Figure 12.

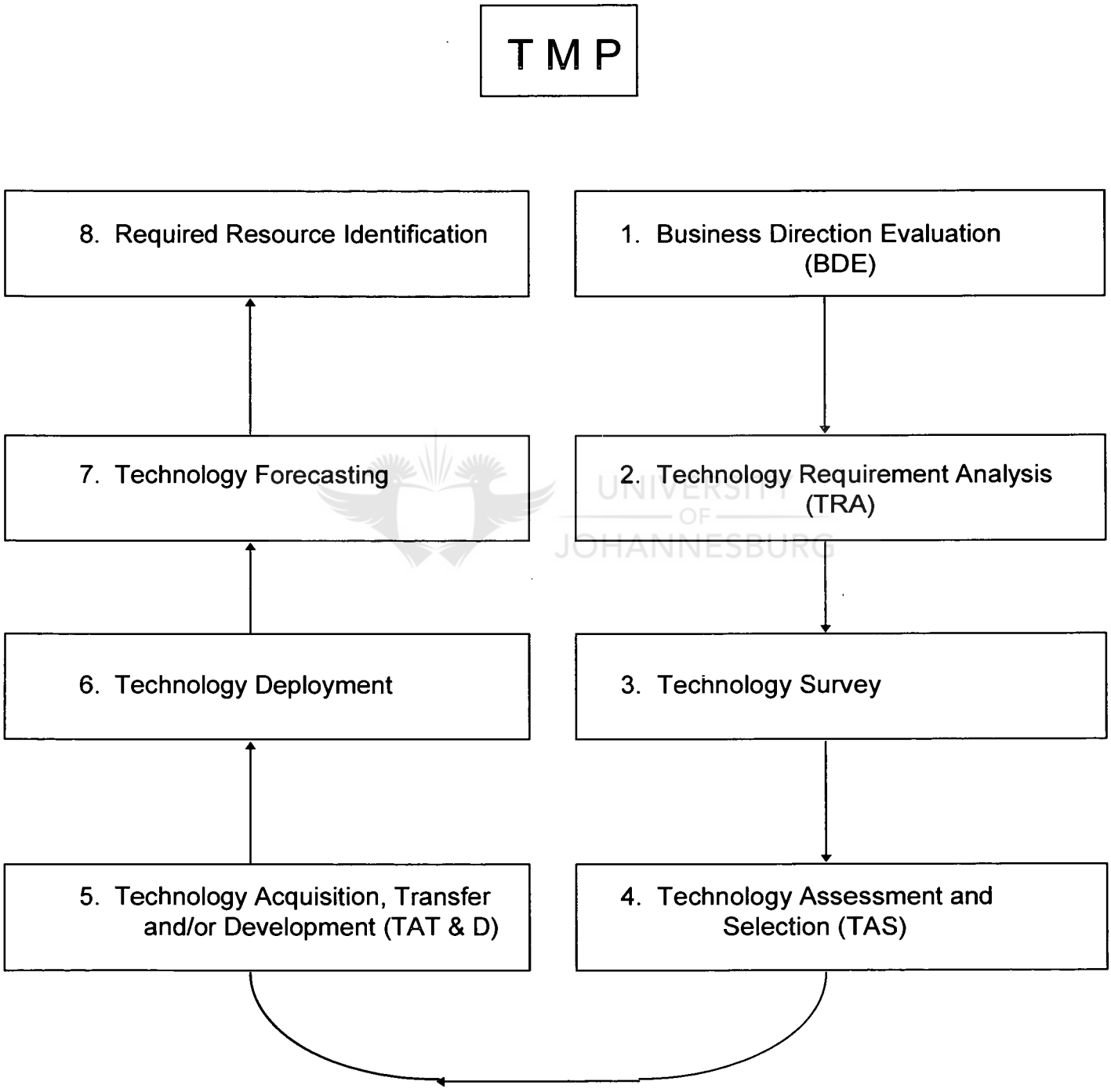

Figure 12 : Functional Components of the Technology Management Plan (TMP)

Consideration of the diagram, leads to a discussion of the functional components and the role they play in defining the Technology Management Plan.

4.1 Business Direction Evaluation (BDE)

The first step in the development of the TMP involves the process of establishing and defining the core competencies of the business. This basically evolves around the following question: What business is the organisation in ?[74] The core business evaluation leads to the formulation of specific areas in which the business holds key competencies[12] and affirms or disputes these areas as the core business of the organisation[68]. The technological competence of a business is thereby forced to be addressed.

Defining the core business areas or aspects of an organisation can also assist the institution in realising, and consequently aiding in the establishment, of possibly emerging competencies within the group. These might offer opportunities for exploitation in terms of additional or new market environments. However, this information needs to be known and available and the awareness of these aspects can best be dealt with by performing a business direction evaluation. A great deal of literature[6,12,14,15,17,21,24,32,40,49,52,68,70,74,87,100,106,107,115,119,124] is available concerning this topic and various methods have been proposed to address and conduct such an evaluation. Some of the more commonly employed phrases describing the above are: scope analysis, core business assessment, strategic thrust, mission and vision evaluation and business focus and activity definition.

Terminology which explains and describes some of the specific methods employed in conducting these evaluations, can typically be related to the following activities: scenario planning, product-customer matrices(PCM), market-driven transformation modelling, core capability value chain derivation, continuous improvement and business transformation processes, as well as

case studies analyses. Each of these aspects addresses, although in slightly different manners, the all important questions, namely: "What business are we in? Why are we in it? And; What capabilities do we require in order to take advantage of current and potential market conditions?" These capabilities, at least for the development of the TMP, should therefore include an accurate "stock-taking" on the current technological capability of the organisation.

In this light, the business direction evaluation serves the function of realistically defining where the organisation is currently with regard to its competitive environment. The importance of such an evaluation lies therein that not only is it vital to know whereto the business aims to develop, but it is also imperative that the organisation establishes exactly from which platform this envisaged development is to evolve and proceed in the future. The point from which business development proceeds greatly influences the resource needs. The evaluation methods referred to above, therefore establish the nature of the organisation, its fundamental purposes and its objectives; indeed its reason for and anticipated direction of existence.

There are probably as many approaches to performing a business direction evaluation as there are organisations; this is predominantly due to the individuality of each institution, its unique background and historical trends. Although many approaches exist, the following multi-dimensional generic model[(adapted 74)] can be applied to most organisations, in order to yield a business direction evaluation which will enable the organisation to guard against the less predictable external forces and hence, position itself better towards the future. The model comprises of an investigation into four key dimensions. These are formulated by the following questions:

1. ***Who is being served?***

   This aspect addresses the market segment in which the organisation functions. In essence, the answer to this question must clearly identify who are the customers of the business.

2. ***What needs are being satisfied?***

Here the consideration is on what customer functions are being satisfied by the company's services or products. Attention must be given to exactly what activities and roles the organisation's products or services fulfil for the customer. This requires a look at the business through the eyes of the customers[124].

3. ***In what stage of the overall value chain do the products and services offered, fall?***

This question addresses the position of the company's products or services in the overall value chain (i.e. from raw materials to final product). Consideration of this aspect often leads to the realisation of product or service transferability. This in turn, can result in new applications being identified and the creation of new markets[12,17,29,35,72,92,109,118] or potential areas of benefit[62,66,103,115].

4. ***How are customer functions satisfied?***

This aspect addresses what technology or technologies are currently employed in order to achieve the above. Consideration of the technology dimension is vital for the subsequent development of a technological scope. The objective of the technological scope is to comprehensively identify exactly what technology is in use, in addition to where and for what reason (i.e. technological applicability and function) the specific technology is applied. The answers constitute the starting point for the next stage of the TMP.

In answering these 'deceptively simple' questions[74] sequentially, it is important to note any interactions between the factors, as well as the impact on them of external forces. This, in effect, will enable the organisation to determine 'what is', 'what has happened' and 'what should happen'. Due to extremely competitive and dynamic market environments[50,72,92,109], the business direction evaluation (BDE) should receive consistent attention by prolonged consideration of the multidimensional key aspects of products

and/or services offered. This will lead to enduring concepts regarding the nature of the organisation, its fundamental purpose and its envisaged future.

The performance of the business direction evaluation will thus, as one of its outputs, produce the technology scope. This must identify what, where and why specific technology exists within the organisation currently. A general and holistic approach is required at this stage, rather than an in-depth investigation. It is important to consider and include all possible technology applications (i.e. a 'wide' approach) rather than a detailed assessment of the technology scope existent within the organisation. In line with the future direction of business, the currently available level of technology can then be employed as a basis for the second step of the TMP development.

4.2 Technology Requirement Analysis (TRA)

The technology requirement analysis forms the second functional step in conducting the TMP. It utilises the technological scope of the business as a starting point for determining exactly what technology is required in order to fulfil or enable the achievement of the future prospects (as determined in the first step) of the organisation. A formal step is required because it is now necessary to assess and evaluate the current level of technological competence and capability within the group[28,33,114], based on where the business wants to focus. This differs from simply establishing what technology is in use in the organisation at this stage, as was determined by the technology scope in step one of the TMP. Furthermore, the analysis pivots around the measurement of the available level of technological capability in comparison to what is considered to be required for the future, if the future business goal or mission wants to be attained.

Consideration of these aspects immediately leads to the following question: What level and type of technological capability will be required to successfully meet the future business goal? A clear understanding of the required technological capabilities thus proceeds the measurement step of current

technology level versus required technology level. Before the 'shortfall' of technological competence can be established, it is therefore vital to establish the future technological requirements.

It is desirable and indeed, important to document this process very clearly, as iterative reflections thereon will indicate exactly the path of technology requirement analysis followed and will result in faster and more clearly understandable future analyses. It has been established[49,70,107] that once the need for change has been identified and confirmed, it is absolutely vital for business success, to implement and initialise the process of change without further delay. In other words, the speed of change[49,70,107] is considered as a critical factor in successful organisational change. Correct, comprehensive and up-to-date documentation of not only this second TMP step, but indeed the complete TMP process, will definitely help to ensure that the time spend planning and adopting to new challenges, is minimised. This inevitably improves the process (TMP) responsiveness, thereby directly sustaining the alertness of an organisation.

The required level of technology for future application and utilisation will most definitely be addressed on the basis of the multidimensional key factors and questions identified and discussed in step one. This ensures continuity and enables comparative measurement of the levels of technological capabilities in each case. However, in conjunction with these factors, future prediction exercises, such as scenario planning, with specific emphasis on technology requirements in relation to future market challenges and conditions, may also be applied with merit. This differs from technology forecasting in that the development and prediction of technology is not mathematically addressed, but rather the influence of the environment is allowed to act[95] and assist in the prediction of possible technological needs. The result yields a typical 'what if' or 'once upon a time there was the future' approach[14,21,100] and could help to crystallise what level of technological competence will be required in terms of fulfilling the goals of the business direction evaluation.

The output of the technology requirement analysis will therefore, not only present exactly what future technological capabilities need to be obtained, but also indicate the relative gap between the current and required levels of technology. This will allow the organisation to broadly quantify the anticipated costs associated with the establishment of the required level of technology.

4.3 Technology Survey (TS)

The third step in the development of the TMP, can be referred to as a technology survey. During this stage, the objective is to perform thorough investigations of all relevant technologies available. From the onset, it is important to realise that the definition of 'relevant' technologies can hold some danger in terms of overseeing technologies existent in other areas of business or operation, which could however, upon knowledge thereof, become integrated and useful for the business' own application. This implies that care has to be taken to conduct a search of technology sources and forms[78] across a wide field, thus requiring an interdisciplinary approach to the survey. This means that forms and levels of technology in non-related fields and environments also have to be regarded. Awareness of the potential of out-field technologies is an important aspect for new, innovative[24,35,90] applications of technology within an organisation's base field.

In order to conduct a meaningful technology survey, it is necessary to employ a methodological approach[113,120]. The first step is to define the area of technology that is to be surveyed. It is necessary to identify which aspect of the technology search needs to be emphasised, as well as prioritised. The definition step often distils the overall topic into key words, phrases and functions of the technology, which can be used directly in the search. The second step of the survey is to identify all sources of the technology field under investigation. This is where care has to be taken not to disregard sources which, at first, seem useless for the organisation's anticipated needs. Various technology sources exist and they can broadly be divided into the following groups[78,113]: Printed literature (traditionally papers and books

constituted one of the greatest sources of technological information, but lately these have increasingly been replaced or supplemented by electronic, on-line information); Internet and other electronic information systems, topic-authoritative personal sources (e.g. individuals with acknowledged expertise in specific areas of technology); institutions (such as universities, research centres and professional societies or institutes; from private to governmental); exhibitions, symposia and conferences and new product or service launches. Many of these sources do not operate in isolation and often interact and span across one or two of the different sources of technological information. However, for the purpose of visible identification and in order not to disregard their consideration in the survey, these sources of technological information are regarded on the above basis. It is clear that, for example during institutional seminars or conferences, printed literature will also play an important role as a technology source.

The aspect of printed literature, both of published and unpublished nature[42,43], forms an expansive grid for the consideration of technology. Not only do large and small corporations alike, communicate 'on paper', but most organisations store valuable information on some form of organised database(MIS)[83,85,91,123]. Openly available databases (electronically), such as Dialogue, Sabinet etc.[113] can form an absolutely vital link in establishing further references (e.g. literature) and leads as sources of technology, through the correct use of the key words identified in step one of the survey. In such a manner, the sources of technology become inter-related and cross-linked. As an example, consider the initial source of technological information as printed literature. A subsequent search on printed literature may reveal technical papers (in journals) and books, key individuals in the specific technological environment and institutes operating within the field. One of the most utilised sources for identifying new technological applications lies in patent registrations[11,42,43,90] at national patent offices. However, South African patent registrations have been found to be of an adaptive nature, with few of the applications functioning on a completely new technological basis[90].

The South African area of university-industry as a technology source, has attributed the failure to commercialise new technology inventions and abilities (as often identified and developed by universities) in the industrial arena, as one of the reasons for not making this a more successful technology source[90]. An improved level of liaison between universities and industry[56,69,90] is required in future, in order to fully assist in the development and employment of this potential technology source.

Many organisations which have recently undergone some form of business transformation(e.g. Reframing Corporate Direction, Restructuring the Company, Revitalisation of the Enterprise and Renewing people(4 R's)[40,52]), have published literature available which could be employed as guidance in the area of technology source identification. In addition, the survey process employed by these organisations can yield information in terms of the methodology followed and time required to identify technology sources. This in turn, can assist a business in its own technology survey, as it at least knows how and where to start its survey. The exercise of strategic benchmarking is a typical application of this line of reasoning and benchmarking of the business' own technology as compared to its competitors[119] can bring valuable information in terms of the competitor's technology sources, which in turn can aid in the identification of the organisation's existing and potential technology sources. The scanning or search function of the technology survey can be illustrated by Figure 13, which depicts the need for continued awareness and monitoring of new technologies[38].

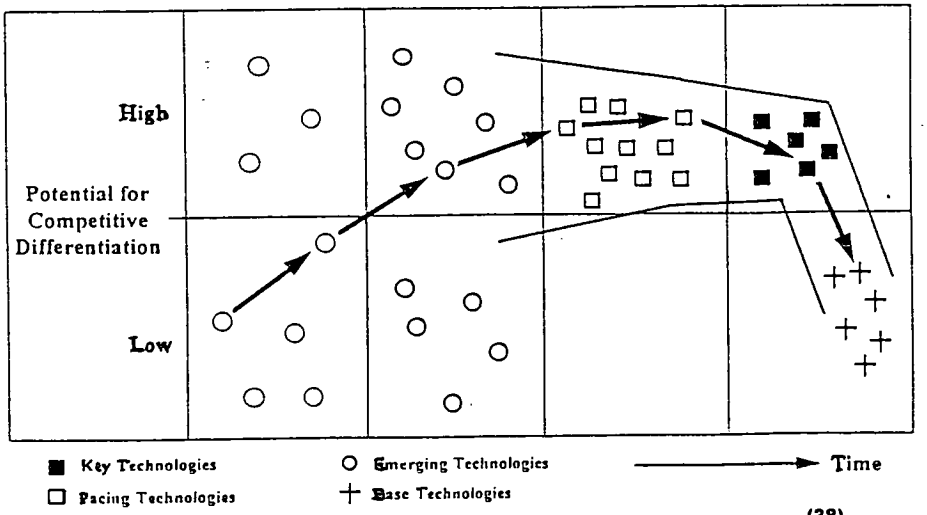

Figure 13 : Technology Scanning and Monitoring[38]

The final step in the technology survey entails the process of obtaining and meaningfully presenting the technological information previously identified. This involves the classification of all technology in terms of availability, current area of applicability and interrelatedness[110]. This systematised perception could be regarded as a form of technology 'balance sheet'[28], however, the aim is purely to list and classify the technologies, their sources and current applications, and not yet to assess the potential thereof. This assessment of technology forms part of the following step in the TMP.

4.4 Technology Assessment and Selection (TAS)

This step entails the detailed evaluation of all the previously identified, potentially viable technologies. This requires an in-depth assessment of various factors of the identified technologies[28,45,83,102,110,120], including their current and potential or future levels of development and areas of business application.

Specific aspects on which the identified technologies are assessed must include the following: the applicability and compatibility of the technology (e.g. to the organisation and its purposes, to the environment etc.), the lifespan of the technology, the function and structure of the technology (e.g. complexity) and the cost and performance of the technology. Consideration and evaluation of these factors allows a comparison to be made between different technologies and leads to the subsequent selection of the best and most required technology for the organisation, in line with its overall business direction and goals.

Technology applicability deals with the consideration of whether or not the technology meets and fulfils the requirements of the organisation. In other words, does the technology pose a solution to the identified requirements or not. In addition, the question has to be asked whether the technology holds the potential to sustain the future requirements in terms of the anticipated business development. This also addresses the issue of technology

lifespan(S-curves etc.[28,37,45,64]) and focuses on the stage of technological development the specific technology has acquired. In certain instances there may be justification for the utilisation of a technology for the immediate and near future, although the technology itself could face being phased out. This is particularly the case if the use of that specific technology is related to attaining a level of technological competence which is already held by the competitors. The consideration of technology cost must therefore also be regarded. The influence of the specific technology's anticipated lifespan, as well as the expected and required level of performance (i.e. is the technology good and how good is it?), are both factors which need to be taken into account when assessing the cost of a particular technology.

Specific performance factors[114] of a technology include aspects such as efficiency, capacity, accuracy, reliability and maintainability[10]. A high cost of technology may be approved upon guarantee of high or superior performance thereof. On the other hand, a high technology cost in conjunction with a low lifespan and low to medium performance levels will definitely result in a more negative decision being made towards the utilisation of that technology. The function and structure of a specific technology plays an important role in the concept of technology compatibility. Whether or not a technology is fully compatible to the existing organisation (its history, systems and most importantly, its people) has been identified as one of the major considerations[37,75,122] requiring focus before a technology is implemented. Indeed, the failure of new technology implementation and utilisation has been directly linked to the level of human and system compatibility[29,37,51,75,87,121,122] a technology exhibits with respect to a potential user.

Consideration of human compatibility of a technology[31] include elements such as the complexity and flexibility[87] of the technology, the level of training[27,81,97,106] and enhanced skills(craftsmanship)[50] which will be required for its operation, the ease or difficulty of use thereof, i.e. ergonomic factors of the technology[105]; whether the technology is psychologically[1,37,94,96] viewed as a threat (both in terms of knowledge required and job-security) by the

employees and the availability of the technology once implemented. This factor can account for high stress levels in employees during instances of low system availability and hence influence the behaviour and attitude of employees towards the technology on an ongoing and widespread (throughout the organisation) basis. The achievement of this human-technological synergy is vital to both the employee and the successful continued utilisation and existence of the technology.

Consideration of system compatibility regarding a technology addresses the physical aspects (e.g. structural (e.g. facilities), energy and space (e.g. compactness)) of the technology[118] with respect to the existing parameters of the organisation. An aspect which can be included in this group and which has moved right to the top of relative importance (e.g. finance, human compatibility) is the consideration of the technology's environmental compatibility[65]. Technologies which exhibit weak or poor environmental features are definitely regarded in a more negative light and governmental and public opinions can strongly influence the planned application and implementation of such a technology. This factor is also of importance in terms of the future environmental status of the technology and has to be regarded in detail. It is of no use to employ technology which has the potential to develop into an environmental and ethical hot pot in the future, thereby possibly scorning the image of the organisation, whilst escalating the cost of utilisation and perhaps even a forced, early decommissioning or phase-out of the technology. Environmental audits on technologies[65,73,95] and ethical considerations[104] have thus proven to be important aspects of the overall modern corporate strategy. In addition, the utilisation of environmentally favourable technology can provide an additional element of competitive advantage for organisations, especially those operating within the publicly visible markets. Consumers tolerate some degree of price increase for products or services with 'green' credentials. This suggests that aspects such as the re-use and recycling of technology must now also be considered as part of the overall status of system compatibility regarding a technology.

Consideration of all these factors, which can best be achieved by a quantitative model employing a combination of a factor-scale (weighting) for relative importance, in conjunction with a point-value (e.g. one to ten) for factor 'performance', will result in an evaluation of technology alternatives[83,104] with an accurate assessment of the potential of all technologies identified. The selection of the best technology or technologies can subsequently proceed on a quantitative basis.

4.5 Technology Acquisition, Transfer or Development

The literature discussing technology management deals extensively with the aspects of technology acquisition and transfer. The aspect of technology development is also comprehensively addressed under the heading of research and development management. This step of the TMP, therefore deals with the decisions an organisation has to take regarding the process of obtaining the technology selected in the previous stage of the TMP. As such, this step forces the organisation to consider all methods whereby the identified and selected technology can be obtained.

Traditional methods of obtaining technology have included the research and development[4,8,19,26,39,55,64,66,75,77,89,92,95,114] thereof. This could be accomplished by either, in-house, external or joint technology development[117] programmes. More recently, the topics of technology acquisition and technology transfer have received great attention[18,19,28,29,34,55,56,70,75,111,118] and many facets of technology acquisition and transfer have been discussed. The aim of this step in the TMP is predominantly to obtain a cost figure for each of the alternatives with respect to obtaining the desired technology. On the basis of these costs, it is then possible to select which method is best suited.

It is important to realise that many factors, a great deal of which are not directly or easily quantifiable, influence the overall cost figure and hence, the decision which route to take in terms of obtaining the necessary technology.

As an example, it can be stated that the cost of establishing a research and development centre for a specific technology can be enormous, yet the continued use, availability and establishment of expertise which results from the decision to proceed with a R&D programme, can hold great benefits for subsequent technology developments. However, these factors are, in conjunction with high staff morale and ambition(e.g. due to the successful completion of such projects)[121], difficult to quantify. A system of allocating relative 'worth' (in monetary terms) could be employed in such cases, in order to allow a comparison with the other methods of obtaining technology. The difficulty in quantifying specific factors of a technology acquisition or transfer route can also emanate from technology licensing agreements commonly entered into. A technology may then be utilised for an organisation, to its advantage, but only for the specific goal intended originally. Normally a novel application of the specific technology to newly emerging areas of application by the second user, is prohibited contractually[118]. The benefit of identifying a new market application for the technology is therefore often limited to the original technology establisher or developer. The loss of the right to explore and specifically exploit further market applications is typically exactly one of the areas difficult to quantify in monetary terms, as such exposure and identification of opportunity is future based and probabilistic in nature.

The aim of this TMP step is to establish a conscious decision making step with regard to the awareness and subsequent selection of one of the alternative methods of obtaining technology[94]. Aspects which need to be considered for technology acquisition and transfer include: Franchising[34]; Motive for acquisition (market oriented entrepreneurship, short-term profit, technological acquirers and pre-emptive market protectors)[18]; Increased competitor alertness through acquisition deals such as licensing agreements, new-ventures, merges or acquisition of companies and/or the acquisition of products or services[118].

In addition to the acquisition/ transfer costs, the role of intellectual property, confidentiality and legal aspects[11,42,43,118] are important considerations

regarding this method of obtaining technology. On the other hand, aspects to be considered relating to the development of technology[4,28,39,89] normally include: time-span for technology development, capital and operational requirements (financial demands), technical competence and potential, manpower demands, organisational suitability (ambition, excitement and interest); project management capabilities and time/market risk[92] and uncertainty. The development of technology normally culminates in a complete more long-term research and/or development project or programme.

An evaluation of the methods by which technology can be obtained will thus result in the selection of either technology acquisition and transfer or technology development (e.g. due to a lack in suitable technology for the specific business purpose) as the method for establishing the required level of technological competence within the organisation. Once the appropriate method of attaining a technology level has been identified, the next phase of the TMP can commence.

4.6 Technology Deployment

Once the necessary technology has been acquired or developed, the deployment thereof can proceed within the organisation. The step can be regarded as an equivalent to the commissioning step in a systems engineering plan (SEP)[10]. This commissioning step of the selected technology involves the implementation and start-up of the technology within the operational framework of the organisation. A key decision in this regard is whether the implementation step should be a gradually phased-in approach or a more rapid, once-off deployment approach. This will be determined by the level of technology to be implemented (i.e. complexity and structure) as well as the extend to which the employees of the organisation have been prepared in terms of the anticipated implementation and utilisation of the technology[75].

Organisations who have invested a fair amount of time and money in the training, informing and consultation of their employees prior to the

implementation of the technology[27] will generally be able to implement quite complex technologies within a relative short phase-in time. On the other hand, employees who have not been properly trained, well in advance, will tend to experience a high resistance to change and hence the deployment stage of the technology will be earmarked by an extensive need for prolonged training and a comprehensive 'campaign' to gain general employee acceptance. The role of this human element should not be underestimated. Only when the concept of uncertainty towards the new technology has been erased[37] will the idea of technological 'threat' towards job-security, diminish. Only then will the deployment of the technology be able to proceed successfully. The technology deployment phase should thus be started well in advance to reaching the end of the technology acquisition phase(The Airbus 320 Example: Swissair versus Air Inter(France) - proactive versus reactive adaptation[37]. Both external and internal business contexts of technology have to be regarded). It is to be understood that specific areas of the technical training might not be finalised yet, depending upon which form of technology acquisition will be decided upon, but at least the concept of implementing and adapting to a new technology in the organisational structure and culture will have been addressed timeously. In addition, enough time will have been allowed to identify specific human training needs or problem areas.

Upon installation of the new technology, the aspect of testing needs to be dealt with. The technology needs to be measured regarding actual, operational system compatibility and performance. These measurable parameters have been extensively defined and dealt with in step four of the TMP. One of the main questions which need to be answered is, whether or not, now that the technology is actually in-place, it is capable of fulfilling the objectives set out initially. In short, does it do the job, now that it is in the organisation?

Once the technology has been deployed successfully, is performing at its required level and all necessary tests and system-checks have been carried

out to ensure that the correct technology has been chosen; the next step of the technology management plan can be started.

4.7 Technology Forecasting

This step comprises of a determination and evaluation of the anticipated changes of the technology in the light of its successful deployment. The basis for such a consideration is the fact that many systems hold the potential for both negative and positive change only once they are really in position and operating. It is often impossible to assess how a technology will develop, change or even demonstrate the potential of change until after its utilisation has commenced. This highlights the fact that theoretical investigations and plans ultimately have to be measured against what is apparent in practice. A good example of this is the relative inability to completely and accurately predict human behaviour. Consider the following scenario as an example:

Notwithstanding many hours of training and costly preparation, the initial acceptance of employees may quickly turn to complete distrust in the technology, e.g. upon the occurrence of an accident whereby the newly deployed technology is directly involved. The subsequent refusal of employees to engage in the utilisation and application of the acquired technology follows. The consequence is apparent; the corporation's investment in technology is perceived to be rendered meaningless, whilst all involved describe the experience as a painful exercise. As the investment bears no immediate fruit, the corporation is unlikely to embark on similar avenues easily in the future, thereby leaving the company open to commercial and market risk, which further negates its competitive advantage. This fully illustrates the potential technology holds in terms of the possibility for negative change on business activities.

Clearly not all of these circumstances could have been predicted before the technology was functioning in-place for a given period and thus underlines and

warrants the importance of considering the possible changes of the technology in a formal step termed technology forecasting[38,110].

It is also important to realise that it is not only the technology that can undergo a change as a result of the surroundings after its successful deployment within the business environment, but also the immediate business environment which can be influenced or forced to change due to the action and forces radiating from the specific technology. This interaction can be graphically illustrated by Figure 14.

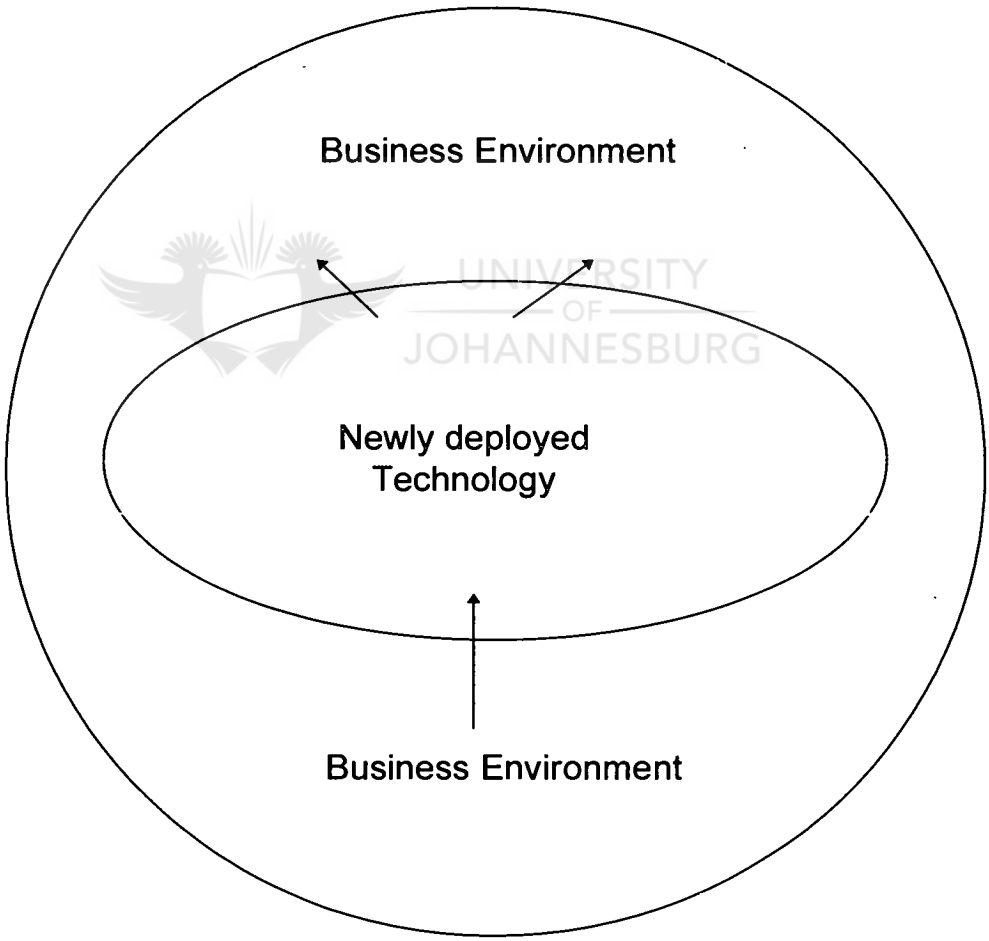

Figure 14 : The technology - business environment interaction

This complex interaction forms the centre of the technology forecasting exercise in that it attempts to predict what interaction will be possible and feasible in the future. Various techniques are available, but the systematic prediction of future performance characteristics and applications of technologies[37,38,75,88,120] can basically be divided into four major categories[110], namely:

- surveillance techniques;
- projective techniques (probabilistic / mathematical);
- normative techniques (goal oriented, e.g. Technology Foresight by Roadmaps approach(at BP)[3]) and;
- integrative techniques(e.g. Delphi forecasting[35]).

The development of these 'pictures' or projections[102] will aid in the identification of growth areas of the technology other than those originally estimated or planned for.

In addition, technology forecasting enables the organisation to fully define and prepare for the complete customisation of the technology to their needs (new and/or original).

Perhaps the most important aspect of the technology forecasting step lies in the possibility to identify spin-offs due to the utilisation of the technology. This is mainly due to the fact that opportunities of positive and negative change can be visualised. The positive opportunities of change can then be regarded as potential spin-off's, whilst the identification of negative possibilities of change enable the management to steer clear of problematic areas, thus avoiding potential conflict and monetary loss situations.

The performance of the technology forecasting step therefore helps in the identification of the complete and realistic role of the technology, its potential and future areas of application with respect to the anticipated change thereof after satisfactory utilisation within the organisation.

4.8 Required Resource Identification

Performance of steps one to seven of the TMP establishes all the resource requirements of the technology for the short to long term of the organisation. The specific resources for short term planning focus on the ability to implement, fuel and drive the acquired technology, whilst resources for longer term planning address the needs of sustaining and maintaining the identified positive areas of change (i.e. the "food for change").

The information obtained from conducting steps one to seven identifies and allows the quantification of the resource requirements for the specific technology in terms of the following requirements:

- Finance(direct cost)
- Human
- Time

Human (required personnel numbers and their associated training) resources translate to a monetary requirement in the final analysis, whilst the time required to conduct the technology management plan can also be translated into a 'time is money' concept.

The Technology Management Plan (TMP) then comprises of all the steps from one to eight. The information so obtained constitutes the overall process of establishing a technology management plan for the proper management of a technology in order to fulfil an organisation's business goals. The ultimate use of technology therefore lies in achieving increased business profitability through the provision of higher added value to the customers.

5. CONCLUSION

It has been estimated[5] that 90 per cent of our present level of technological knowledge has been generated over only the past fifty-five years, whilst of all the scientists and engineers who ever lived, ninety per cent are living and working in this decade.

Furthermore, it has been postulated[5] that our technological knowledge will continue to increase exponentially, probably doubling every thirty to forty years. This results in a decrease of the utilisation time of technological applications(i.e. shortened life cycles[117]), which consequently leads to a higher demand for innovative products and/or services[53] , whilst at the same time increasing the globalisation of technology.

Table IV summarises common myths and realities concerning technology[116].

TABLE IV : TECHNOLOGY MYTHS AND REALITIES[Adapted 116]

Myths	Realities
• Technology drives competition	• Technology only qualifies the business to compete
• Most business failures are failures of technology	• Most business failures are failures of proper management
• The advantages goes to the business with superior technology	• The advantage goes to the business with superior strategy and execution
• The business of technology belongs to technology experts	• The business of technology belongs to all managers
• Investment, utilisation and management of technology is a matter of choice	• Investment, utilisation and management of technology is a necessity for business survival

As the pace of technological change[70,116] is accelerating, the stakes and risks of managing technology are raised. This requires an adequate and comprehensive technology management plan (TMP).

The Technology Management Plan constitutes a process whereby an integrated framework is methodologically evolved and presented in order to address all the relevant aspects necessary for successful technology management. The TMP can be regarded as an eight step route map, which attempts to include the complete scope of functional areas which need to be considered before an organisation arrives at a final decision concerning technology.

The eight functional steps of the TMP can be summarised as follows:

1. Business Direction Evaluation

The first step deals with the process of establishing and defining the core competencies of the business. The main area of focus is to answer questions such as: What business is the organisation in ? Why ? What are the business' thrust competencies and capabilities ? In answering the questions, a technology scope is produced, which identifies what, where and why specific technology exists within the organisation. At this stage it is important to consider and include all possible technology applications existent within the organisation in a holistic manner, rather than to perform a detailed assessment of and investigation into the level of technology within the organisation.

2. Technology Requirement Analysis

The second step utilises the technology scope produced in step one to determine exactly what technology is required in order to meet the future prospects of the business(as determined during the first step). This involves an assessment and evaluation of the current level of technological competence and capability within the organisation, as compared to what level and type of technological capability will be required to successfully meet the future business goal. This measurement step therefore identifies and establishes the future technology requirements.

3. Technology Survey

This step focuses on the performance of an investigation into all possibly relevant technologies available. Care has to be taken not to disregard technologies currently in operation outside the base field of the organisation. These often hold great potential for innovative sources of new technology applications. Furthermore, in order to conduct a meaningful technology survey, it is vital to employ a methodological approach to the survey. Various technology sources are to be considered during the course of the survey, followed by a classification of the different technologies in terms of availability, applicability and interrelatedness.

4. Technology Assessment and Selection

During the fourth step all the previously identified, potentially viable technologies are subjected to a detailed evaluation. Various aspects and factors are employed as references with respect to the rating of different technologies, some of which include aspects such as the applicability and compatibility of the technology to the organisation and its purposes as a whole. Specific factors under consideration include human/ergonomic, environmental and system compatibility, as well as the cost and performance levels of the technologies. Final selection of the most viable technology or technologies subsequently proceed on a semi-quantitative basis.

5. Technology Acquisition, Transfer or Development

This step deals with the decisions an organisation has to take regarding the process of obtaining the technology selected in the previous stage. As such, this step forces the organisation to consider all methods whereby the identified and selected technology can be obtained. Possible areas of obtaining technology include the research and development thereof by either in-house specialists, external or joint developments. In contrast to this, technology can also be acquired and/or transferred from existing sources of competence. Various factors, many of which are not easily quantifiable, play both roles of pro and con with respect to each of the methods of obtaining the required technology. The aim of this step is twofold; firstly, to create an awareness regarding the existence of alternatives in terms of obtaining technologies, and secondly, to generate cost figures for each of the alternatives under consideration.

6. Technology Deployment

This step involves the commissioning of the technology within its new operational environment and includes aspects such as the implementation, preparation and start-up of the technology. Attention should be given to proper preparation having been conducted prior to the phase-in of a new technology, particularly in the arena of employee acceptance. The role of the human element in successful technology deployment should not be underestimated. The aspect of testing and specification compliance measurement are also included in this step. In short, does the technology perform as originally desired, now that it is operational within the organisation ?

7. Technology Forecasting

During this step attention is given to a determination and evaluation of the anticipated changes and their effects regarding the technology, viewed in the light of its successful deployment. The objective is to identify the potential for both positive and negative changes and to react accordingly. Positive changes due to advantageous business environment - technology interactions can be employed as additional spin-off's for the organisation, whilst the identification of negative possibilities affords management the opportunity to timeously steer clear of problematic areas, thereby avoiding conflict and potential monetary losses.

8. Required Resource Identification

The final step focuses on the establishment of all the relevant short and long-term resources which will be required to sustain the successful management of the technology across its lifespan. The final monetary resource value is based on the quantification of individual resource requirements for the technology in terms of direct cost, as well as human and time requirements.

In order for any organisation to survive in the modern marketplace, it is imperative for that organisation to embark on the journey of improved global competitiveness. Technology management forms one of the cornerstones of the modern business environment and the aim of the technology management plan (TMP) is to provide a tool for attaining a level of global competitiveness.

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