The Enigma Of Technology Management In Strategy Deployment

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ABSTRACT

The ever-increasing emphasis on knowledge acquisition and assimilation is forcing companies to focus on methods to improve their effectiveness in technology management. Corporate strategists are increasingly focusing on the integration of technology throughout the organisation as a source of sustainable competitive advantage. The purpose of this study was to investigate technology management principles in widespread use in technology intensive industries and to explore their relationship to company performance. A non-probability, judgment sample of companies listed on the Johannesburg Stock Exchange (JSE) were taken. The study makes a contribution to the field of strategic management research by integrating the dimensions of several previous studies, to derive a more comprehensive taxonomy of technology management archetypes. Two distinct technology management factors obtained with the analysis were proved to positively influence the company performance dimensions and were classified as R&D Commitment and Control Market Planning factors. The results show that strategic management choices can significantly affect company performance. It thereby indicates which of the underlying dimensions have the strongest relationship with company performance. From an industry perspective, the greatest significance of these findings may be that they accentuate the importance technology management in developing and implementing a strategic approach to technology. This study has expanded on the identified technology process dimensions and has highlighted the link between technology strategy and technology management through different measures of performance.

Keywords: Technology Management; Technology Intensive Industries; Company Performance; Control Market Planning; Process Management; R&D Commitment

INTRODUCTION

Technology is seen as a major driving force behind core competence development and increasing company performance. For some companies, setting policies regarding the technologies, which have an impact on their operations, is the same as developing their strategies (Pelser, 2014a, 2014b, 2014c, 2014d). During the 1980s and 1990s new research journals, such as *Technology Management, Technology Studies, The Journal of Engineering and Technology Management*, and *New Technology, Work and Employment*, were founded, to stimulate and expose the source of research on technological change and the management of technology. A small number of universities, realising the impact of technology on profitability, have offered business courses in technology management. This in part, had reflected the growing demand for managers and technologists who are able to understand, contribute to, and manage a multi-disciplinary approach to technology-based programs and companies (Nambisan & Wilemon, 2003). Other universities have adopted textbooks for their production and operations management (POM) courses, which included a chapter on technology management. Unfortunately, these POM textbooks cover only already established technologies, which are being used in different operations (e.g., robotics, computer-aided design, and telecommunication), but seldom deal with the detail of making technology decisions as part of the long-term strategic plan (Pelser, 2001).

According to Somsuk and Laosirihongthong (2013), technology management studies were left for large companies, some government and semi-government institutions, and a few individual entrepreneurs. Universities taught either the techniques for developing technologies, or older generation technologies. Neither industries nor universities appreciated this situation. In related areas, such as quality management, industries have blamed universities for not covering the subject at the required level of detail and universities have blamed industry for being reluctant to provide academics with hard data, despite their willingness to disguise such data and the names of the corresponding companies.

Pelser (2001) is adamant that technology plays a pivotal role in interactions among the individual, society, and nature. Technological advances have major effects on each of these entities and are, in turn, influenced by them. Management of technology involves developing an understanding of these relationships and dealing with them in a rational and effective manner. The widely acknowledged importance of technology will grow; increasing the emphasis executives must place on their companies' ability to compete through technology (Nambisan & Wilemon, 2003). The progressiveness of technology management, however, goes beyond basic research and development (R&D) expenditures. Increasingly, corporate strategists are focusing on the integration of technology throughout the organisation as a source of sustainable competitive advantage (Song, Zhao, & Di Benedetto, 2013). This particular study builds on the previous works of Pelser (2014a, 2014b, 2014c, 2014d) regarding strategy taxonomies and their link to company performance.

LITERATURE REVIEW

Over a period of centuries, companies were required to depend for the commercialisation of new products and the improvement of productivity on unplanned findings, which were either derived from worker's "learning-by-doing" or copied from the findings of external scientists and engineers. Research and development (R&D) laboratories began to be established approximately a century ago, because of the prospect that such laboratories would establish consistency into the process of generating new knowledge (Brockhoff, 1998). This form of management has not remained unchanged, but has undergone considerable development according to Pelser (2014d). The focus of these changes are on the systematic integration of strategic technology management into corporate management (Pelser, 2001), so that plans can be made for the required combination with the users of the knowledge further along the value chain. Secondly, decisions are based more strongly on economic considerations, in order to estimate the opportunity costs and profits of internally generated research and development (Pelser, 2001). Thirdly, coordination is required between internationally distributed R&D laboratories and multi-project management, which frequently reaches beyond the boundaries of the company (Pelser, 2001). Hence, Pelser (2001) also advocates the development of capabilities, so as to recognise and to make use of the opportunities offered by new technologies.

According to Thongpapanl (2012), the management of technology links engineering, science, marketing, operations, human resources, and other management disciplines to formulate strategy, develop technological capabilities, and apply them to achieve strategic objectives. This study follows the usage of Clark, Ford, and Saren (1989), who use the term to refer to the organisational issues and the processes involved in developing and implementing a strategic approach to technology. Technology management thus relates to the process aspects of technology policy (Harmon, & Davenport, 2007).

The seminal work of Werther, Berman, and Vasconiellos (1994) outlines the characteristics of the technology management function by emphasising the precise distinction between technology and technology management. According to the authors, technology addresses the application of scientific and engineering knowledge to the solution of problems, while technology management is the integration of technology throughout the company as a source of sustainable competitive advantage. Furthermore, the authors suggest, that the changing dynamics of technology management can be classified as an evolving technology paradigm for competitive advantage. In concluding their scientific study, Werther et al. (1994) advocate that the technology management function was previously not recognised in the management theory, because limited clarity was associated with it.

The strategic approach has evolved from the control paradigm, which argues for an integration of technology with corporate strategy (Pelser, 2001). Technology has been seen as an essential component of the strategy and forms part of the strategic thinking and planning process (Pelser, 2014a). Companies will concentrate on constantly refining their abilities to acquire and deploy relevant technologies, which will be treated as an integral part of their corporate strategies. The technology leaders will be faced with technology acquisitions and deployments. Hence, sustainable competitive advantage will be realised only from the company's ability to become skilled at the technology acquisition and deployment tactics (Pelser, 2014a, 2014b, 2014c, 2014d).

Technology Acquisition and Assimilation

The ever-increasing emphasis on knowledge acquisition and assimilation is forcing companies to focus on methods to improve their effectiveness in technology management. A study of companies in Sweden, Japan, and the United States revealed that the external acquisition of technology was the most prominent technology management issue in multi-technology companies (Granstrand, Bohlin, Oskarsson, & Sjoberg, 1992). The role of traditional technology or R&D management has focused on the management of internal R&D (Seaton & Cordey-Hayes, 1993). Current management studies suggest, that the external acquisition of technology emphasises increasingly important challenges for technology managers (Pelser, 2014a, 2014b, 2014c, 2014d).

Trott (1998, pp. 201-205) discuss and summarise six available internal and external forms of organisational R&D:

1. *Centralised laboratories.* The main advantage with this form of internal R&D, is the concentration of skills. The majority of companies that are working towards technological leadership, centralise their R&D operations.
2. *Decentralised laboratories.* The main advantage of decentralising the R&D function, is to reinforce the link with business, its products, and its markets. However, the drawback with this internal form is, that it can lead to an emphasis on short-term development by providing each unit with its own R&D effort.
3. *Internal R&D market.* It involves establishing a functional cost centre, where each strategic business unit (SBU) pays for any R&D services required.
4. *Contract R&D.* This external form of R&D is suited in a situation where the company has a low level of understanding of the technology and/or when the company does not have the in-house capability to undertake the research.
5. *Collaborative R&D*. Strategic alliance is a generic term for all forms of co-operation, where the costs and potential benefits from an R&D project will be shared. In addition, it also reduces the risks associated with an R&D project.
6. *R&D Consortia*. The main advantages of this approach are the ability to reduce costs and risks, the ability to access technologies and to influence industry standards on new technology. Due to this power base, governments impose harsh penalties on those companies displaying cartel behaviours.

There is a significant difference between acquiring externally developed technology and external R&D. This difference lies in the level of understanding of the technology involved, frequently referred to as prior knowledge. For example, the purchase of new computer software will lead to the acquisition of new technology. This is an alternative available to most companies, irrespective of their prior knowledge of the technology. However, by developing an R&D strategic alliance or an external R&D contract with a third party necessitates a high level of prior knowledge of the technology. Likewise, recent findings (Sabidussi, Lokshin, de Leeuw, Duysters, Bremmers, & Omta, 2014) indicate that synergies exist among external sourcing modes, where different external sourcing modes is more effective than specializing in a single mode, especially when the specialization is focused on alliances.

Technology Performance Measurement

Hansen (2010, p. 17) remarks, that in many manufacturing companies' managers do not have adequate measures for evaluating company performance or for comparing overall performance from one subsidiary to the next. The author go further by stating that the traditional cost-accounting figures can be used, but that these figures do not represent the true nature of company performance. What Hansen (2010) found even more disturbing, is that private sector accounting systems, as traditional management information systems, which are supposed to represent the organisational reality, are problematic themselves. The major reason for this problematical aspect is that accounting systems represent the same reality differently and simultaneously. For instance, there is one representation for management, one for the trade unions, one for the financial community, one for the Receiver of Revenue, and finally one for the shareholders. It is under these circumstances that accounting systems are subject to change, because they "deformate" reality (Halachmi & Bouckaert, 1994, p. 19).

Companies are increasingly finding themselves in business environments facing rapid increases in both turbulence and complexity, leading to enhanced uncertainty and increased competition. This has led to an increased focus on technological innovation as a means of creating and maintaining sustainable competitive advantages (Hamel & Prahalad, 2006). In the wake of this development, the efficiency and rapid access to knowledge and information is becoming paramount. Consequently, investing in technology and the measurement thereof, have surged during the last decade.

Zahra & Hayton (2008) established that the literature on performance is very extensive, but that it shows a lack of consensus as to the meaning of the term. Brush & Vanderwerf (1992) further point out, that the use of the term "performance" by researchers, includes many constructs measuring alternative aspects of performance. This is consistent with the finding of Murphy et al. (1996) who, after a comprehensive literature review, were able to isolate a total of 71 different measures of performance.

Technology Management Dimensions

This study follows the usage of Clark et al. (1989, p. 215), who used the term *management of technology* (MOT) to refer to the organisational issues and the processes involved in developing and implementing a strategic approach to technology. The technology management or process dimensions are taken from many of the same sources as the technology strategy dimensions. As with the content dimensions, the process dimensions chosen for this study represent a consolidation of those cited most often in the research. For this reason, technology management is measured through the use of six process or technology management dimensions (Pelser, 2001):

Technology Awareness

Technology awareness refers to a company's scanning processes, specifically the emphasis it places on acquiring information about emerging technological threats, opportunities and sources (Clark et al., 1989; Dvir et al., 1993). It is measured in terms of the emphasis placed on staying informed about emerging technologies or competing technologies and the awareness of different technology sources:

- Awareness of technology sources.
- Awareness of competing or emerging technologies.

Technology Acquisition

Technology acquisition refers to the methods by which companies acquire technology internally or externally (Maidique & Patch, 1988; Clark et al., 1989). It is measured in terms of the emphasis a company places on acquiring technology from internal R&D activities and from external research institutes or other companies:

- Technology acquisition through internal R&D.
- Technology acquisition from research institutes and from other companies.

Technology and Product Planning

Technology and product planning refers to the formal planning processes that companies utilise to select and manage R&D programs (Maidique & Patch, 1988). According to Lee, Yoon, Lee, and Park (2009) technology planning involves the reformulation of technical terms and objectives into business terms and objectives. It is measured in terms of the emphasis a company places on formal product plans that are market-driven and formal technology plans that are product-driven:

- Using formal product plans that are market-driven.
- Using formal technology plans that are product-driven.

R&D Organisation and Management

R&D organisation and management refers to the degree to which R&D activities are linked to other business operations and the methods companies employ to organise, empower and encourage R&D personnel (Eng & Ozdemir, 2014; Maidique & Patch, 1988). It is measured in terms of the emphasis a company places on integrating R&D operations into product division operations and managing R&D personnel based on R&D project success:

- Integrating R&D operations into product division operations.
- Evaluating and rewarding R&D personnel based on R&D project success.

R&D Investment

R&D investment refers to the methods by which companies fund R&D activities (Tsai, Hsieh, & Hultink, 2011) and the emphasis placed on achieving a specified return on investment (Clark et al., 1989). It is measured in terms of the level of investment the company commits to R&D activities relative to sales and the emphasis placed on achieving financial leverage for R&D investments through external funding:

- Maintaining high level of R&D investment relative to sales.
- Acquiring external funding for R&D projects.

Manufacturing and Process Technology

Manufacturing and process technology refer to the degree to which new technology is incorporated into the company's manufacturing plants and processes (Zahra & Covin, 1993). The appropriate manufacturing technologies can provide the company with considerable operational and competitive benefits (Sohal, 1995). According to Swann and O'Keefe (1990), these include improvements in quality, inventory control, customer lead times, machine use and efficiency, staff efficiency, and customer image (Beukes, Prinsloo, & Pelser, 2013). Ensminger, Surry, Porter, and Wright (2004) points out, that technical success is often widely accepted as successful implementation. However, he observes that the prime motivation for investing in manufacturing and process technology is to improve company competitiveness. This competitiveness flows from gains in such system characteristics as responsiveness, quality, and flexibility. Therefore, technical success is a necessary, but not sufficient, condition for business success (Garnett & Pelser, 2007). It is measured in terms of the emphasis a company places on the use of technology to achieve low manufacturing costs or to manufacture unique products and to improve production flexibility or reduce lead-times:

- Use of technology to achieve low manufacturing costs or to manufacture unique products.
- Use of technology to improve production flexibility or reduce lead-times.

Company Performance

As mentioned in the introduction of this article, this particular study draws on the previous works of Pelser (2014a, 2014b, 2014c, 2014d) regarding strategy taxonomies and their link to company performance for the independent variables.

Zahra and Hayton (2008) established that the literature on performance is very extensive, but that it shows a lack of agreement as to the meaning of the term. Brush and Vanderwerf (1992) indicate that the use of the term "performance" by researchers includes many constructs measuring alternative aspects of performance. This is consistent with the findings of Murphy, Trailerm, and Hill (1996) who, after a comprehensive literature review, were able to isolate a total of 71 diverse measures of performance.

In spite of this apparent abundance, the vast majority of studies have used financial measures of performance (Murphy et al., 1996). The explanation for this fascination with financial performance measures is established partly in the fact that financial performance is at the core of the organisational control systems and partly in that it is one of the most straightforwardly quantifiable measuring instruments. For example, Lussier (1995) argues, that in studying the benefits of technology, instead of analysing macro-economic data from governmental statisticians, micro-economic corporate financial results, certified by auditors, should be used. However, this has caused empirical research to rely on a thin set of accounting measures of financial performance, such as return on investment (ROI), return on assets (ROA), or earnings per share (Pandian, Thomas, Furrer, & Bogner, 2006; Sapienza, Smith, & Gannon, 1988).

When using accounting measures for measuring company performance, a couple of issues should be taken into consideration. First, financial records are in general difficult to interpret, even if accurate financial data are reported (Cooper, 1979). Second, absolute numbers on financial performance criteria are affected by industry-related factors (Miller & Toulouse, 1986). Directly comparing financial data for companies in different industries could be misleading; even if the sample contains companies from the same industry sector, they may include companies operating in different markets. Third, accounting measures may be susceptible to accounting method variation, and lastly, accounting measures are not always representative of the actual performance of the companies, as many company directors for a variety of reasons manipulate performance reporting.

Despite the fact that financial performance is evidently important for the company, it draws only on the economic dimension of performance, neglecting other important goals of the company (Venkatramen & Ramanjan, 1986). This argument is supported by Zahra and Covin (1994), who argues that research that considers only a single performance dimension or a narrow range of performance constructs (e.g., multiple indicators of profitability), may result in misleading descriptive and normative theory building. According to the author of this study, it is unlikely that any single performance measure or dimension could serve the needs of a diverse set of research questions. This view is also shared by Zahra and Hayton (2008), who points out, that a multi-dimensional construct provides an alternative in establishing valid operational definitions. Further to this, Murphy et al. (1996) argue, that a distinction between performance measures should be done on the grounds of whether the sources are secondary data (also known as archival) versus primary data (e.g., questionnaire interview).

The innovation management organisation (IMO) is responsible for developing new products and technologies (Pérez-Luñoa, Wiklundb, & Cabrera, 2011). Science and technology from the external environment are combined with the company's in-house skills, knowledge, and competencies to develop new products and technologies. The responsibilities that fall within the domain of innovation management encompass research and development (R&D). For this reason, R&D consists of those activities and responsibilities ranging from understanding progressive technology to generating ideas to developing new products and technologies. Understanding the dynamics of the innovation management organisation (IMO) is important to understanding the role and impact of strategic leadership of innovation in technology intensive companies. The conceptual definition is, therefore, the extent to which the R&D manager or other top manager perceives that the IMO has achieved its desired objectives over the last three years (Pelser, 2014a, 2014b, 2014c, 2014d).

PROBLEM STATEMENT AND RESEARCH QUESTIONS

Technological progress has major effects on each of these entities and is, in turn, influenced by them. As competitive pressures amplify, the need to continuously adapt, develop, and innovate has become a customary requirement for organisational excellence. Weaknesses to innovate, eventually lead businesses to stagnate and fade away in the face of a dynamic environment (Pelser, 2001).

The 2011-12 R&D survey, conducted by the Human Sciences Research Council (HSRC, 2014), shows that South Africa's performance remains far below the government's initial target of spending 1% of GDP on R&D by 2008. South Africa had spent R22.2bn on R&D in 2011-12, or 0.76% of GDP. This was precisely the same ratio reported for 2010-11, and is noticeably down on previous surveys: it was 0.87% in 2009-10, 0.92% in 2008-09 and 0.93% in 2007-08. These findings emulate the global trends of slowing growth in R&D investment in many parts of the world as a result of the recent global financial crisis. Unfortunately for South Africa, it also trails far behind the international average of 1.77%, and lags most of the other members of BRICS (an association of five major emerging national economies: Brazil, Russia, India, China, and South Africa). China currently spent 1.84% of GDP on R&D, Brazil 1.16%, and Russia 1.09%.

There is thus a critical need to understand the key factors that lead to innovation excellence, the organisational and environmental innovation, and the importance of innovation strategies (Pelser, 2014a, 2014b, 2014c, 2014d). The main purpose of this study is to investigate technology management principles in widespread use in technology intensive industries and to explore their relationship to company performance. The problem addressed in the study, is the need for a better understanding of the role that technology management play in determining company performance. The study focuses on two central questions:

1. What is the prevalent technology management dimensions being employed by South African companies in technology intensive industries?
2. What relationships can be observed between the technology management dimensions and company performance?

RESEARCH METHODOLOGY

The data gathering and analysis phase of the study adheres to the same methodology as applied by Pelser (2014a, 2014b, 2014c, 2014d) regarding strategy taxonomies and their link to company performance and had the following three objectives:

1. Gathering data along key technology management dimensions from R&D managers of technology intensive companies.
2. Gathering objective data about the performance (input and output) of those companies selected for the study.
3. Analysing the data using multivariate statistical methods to explore the relationships among the technology management dimensions and company performance.

Data Requirements

The number of dimensions historically used to develop strategy taxonomies and the variables required to describe them, have varied by researcher (Pelser, 2001). When Miller and Friesen (1977) derived their strategy taxonomies in 1977, they gathered data on 31 variables representing four categories of adaptive behaviour (later classified as strategy dimensions). Galbraith and Schendel (1983) gathered data on 26 variables using the PIMS database. Snow and Hrebiniak (1980) used a 145 item questionnaire to gather data that were subsequently reduced to ten distinctive competence variables and one performance ratio prior to analysis. Cool and Schendel (1987) developed 15 scope and resource commitment dimension variables based on data drawn from a large variety of databases. Fiegenbaum and Thomas (1990) used seven scope and resource deployment dimensions and six performance variables that reduced to three performance ratios. Zahra and Covin (1993) used four dimensions to develop five business strategy archetypes and three dimensions to represent technology strategy. Dvir, Segev, and Shenhar (1993) used Miles and Snow's (1978) four strategy archetypes and two strategy variables.

As the body of strategic management research literature grows, authors of new studies who seek to develop strategy taxonomies are able to take advantage of prior research results to select proven more parsimonious sets of dimension variables. The data requirements for this study were developed by drawing on dimensions identified in prior technology management research (see Pelser, 2001 for a comprehensive discussion). This study follows the usage of Clark et al. (1989) and Eng and Ozdemir (2014), who used the term management of technology (MOT) to refer to the organisational issues and the processes involved in developing and implementing a strategic approach to technology.

Several of the seminal studies on strategic taxonomies gathered research data in the form of management perceptions of their company's objectives or capabilities relative to some benchmark; e.g., the competition's objectives or capabilities (Pelser, 2001). This is consistent with the method recommended by Galbraith and Schendel (1983) and Panagiotou (2007), and is the method employed in the present study. This method also lends itself to answers that can be provided on a normalised five point Likert Scale, with "three" valued answers being "neutral" or "at the industry norm."

The technology management dimensions are the result of a substantial body of prior research and include the key dimensions of technology management development. The dimensions pertaining to this study were derived from seminal literature and are a consolidation of the following studies: Maidique & Patch (1988), Miller (1988), Clark et al. (1989), Dvir et al. (1993), and Zahra and Covin (1993). Table 1 shows the published sources for the dimensions used in this study. The presence of an “X” in a cell indicates that the dimension identified in the column label was derived from the study identified in the row label. For example, the technology management dimension labelled “Technology Acquisition” was derived from comparable dimensions found in four previous studies; i.e., Maidique and Patch (1988), Miller (1988), Clark et al. (1989), and Dvir et al. (1993).

Table 1: The Derivation of Technology Management Dimensions

Authors	Process Technology	Technology Awareness	Technology Acquisition	Technology & Product Planning	R&D Organisation	R&D Investment
Maidique & Patch			X	X	X	
Miller	X		X	X	X	X
Clark, Ford, & Saren		X	X			X
Dvir, Segev, & Shenhar		X	X		X	
Zahra & Covin	X					

A survey of R&D managers of companies listed on the Johannesburg Stock Exchange (JSE) was conducted through the use of a questionnaire. The South African context was chosen both from an operational purpose and the objective to compare the findings with those obtained from studies conducted in other countries or regions. Since the performance of companies in technology intensive industries could be more affected by technology policies than by the performance of companies in other industries, it was assumed that companies in technology industries would be more likely to have technology strategies, thereby making it easier to observe the relationships of interest.

R&D managers from 200 South African technology intensive companies were asked to complete a self-administered electronic questionnaire designed to gather data regarding their company’s technology policies. The questionnaire requested data on the specific industry in which the company operates the technology and innovation strategy of the company and the processes the company employs to develop and implement the strategy. Eighty-four valid responses were ultimately received and used in the study.

Previously published research reports were used to identify a set of technology management dimensions (refer to Table 1). Each dimension measured through the use of two items in the questionnaire. The questionnaire items were designed to permit answers on a five-point interval or Likert Scale. Thirty variables were used to gather data on fifteen dimensions. A survey questionnaire was developed and tested in a small pilot study in order to assess the clarity of the directions and questionnaire items. It was then revised and submitted to five technology strategists to confirm its intelligibility and cognitively confirm the validity of the study dimensions and variables as relating to important factors in strategic management of technology.

A number of company performance dimensions were used as the dependent variables in the analysis of the study.

Despite the fact that financial performance is evidently important for the company, it draws only on the economic dimension of performance, neglecting other important goals of the company. This argument is supported by Zahra and Covin (1994) and Pandian et al. (2006), who argues that research that considers only a single performance dimension or a narrow range of performance constructs (e.g., multiple indicators of profitability), may result in misleading descriptive and normative theory building. Hansen (2010) and Murphy et al. (1996) pointed out, that it is unlikely that any single performance measure or dimension could serve the needs of a diverse set of research questions. The selection of the company performance dimensions resulted in six dependent variables. These six variables were classified in the following two dimension groups.

- Effectiveness of the IMO – (4 input dependent variables).
- Performance of the company – (2 output dependent variables).

The measures selected for this study, demonstrate strong relationships with company performance and had been reviewed in the literature section:

1. Contribution to sales (i.e., right product at the right time).
2. Efficiency of innovation project management (i.e., project success rate).
3. Impact of the innovations (e.g., degree of novelty or technical impact).
4. R&D expenditure (i.e., investment in R&D activities).
5. Patent information (i.e., output of R&D activities).
6. Return on assets (i.e., company financial performance).

Factor analysis was used to reduce the dimensions into identifiable factors. Pearson r-correlation was then used to find the strength and direction of the relationships between the factors and the performance dimensions. The relationships examined, are those between the independent variables and the effectiveness of the innovation management organisation (IMO) and the performance of the company.

Sample Selection

A non-probability, judgment sample of companies listed on the Johannesburg Stock Exchange (JSE) was taken. It was decided to use listed companies on the JSE for two primary reasons: (1) Listed companies display a capacity and capability (capital and human resources) for R&D activities compared to smaller unlisted companies. (2) Quantifiable data (e.g., annual reports) is more readily available for the external stakeholders of listed companies than it is on unlisted companies. The motivation for using the judgment method in sampling was to build a database of those companies most likely to be associated with manufacturing products and/or investing in R&D activities. Based on the abovementioned screening criteria, it was decided to use the Industrial Consumer sector. In addition to this, the following two key criteria were established to select the appropriate companies or divisions within the Industrial Consumer sector for the study:

1. New product development activities, which included tangible as well as intangible products; e.g., computer software.
2. Contact details for the R&D manager or designated top manager responsible for research and development; e.g., Technical Director.

Two hundred companies or divisions were identified and incorporated in the survey after the screening stage. Feedback was received from 89 R&D managers of these two hundred companies, stating their willingness to participate in the survey. A total of 84 completed responses were received and captured for the study. This translates to a 42% response rate from the base of 200 originally identified companies. However, compared to the feedback received from the 89 respondents, it effectively means, that the filtered response rate equates to 94%. The non-response portion of the original sample of 200 companies is comprised of 64 companies. An additional 24 companies have indicated that they are not involved in any type of R&D activities, which automatically excluded them from the study. Another 23 companies provided feedback or reasons concerning their non-participation in the survey, which ranges from vacant positions in R&D key functions to a lack of interest of these type of research efforts.

ANALYSIS OF RESULTS

Descriptive Statistics: Technology Management Dimensions

The basic descriptive statistics of central tendency and measures of variability for the technology management dimensions are shown for variables A21 – A30, A11, and A12 in Table 2. No missing values (N) were encountered with the data capturing process. The lowest mean response turns out to be 3.05 for variable A12. This indicates that the sample is at the same level as their competitors, when it comes to being first to introduce low cost or innovative products.

The highest mean response turns out to be 3.94 for variable A22. The arithmetic average of the responses for variable A22 indicates that the sample of companies is somewhat more aware of competing or emerging technologies than their competitors. The lowest mean response turns out to be 3.17 for variable A30. This suggests that the sample is similar to their competitors when it comes to acquiring external funding for R&D projects. The computation of the variables' standard deviation resulted in value-ranges similar to those obtained for the two previously discussed dimensions.

Table 2: Descriptive Statistics - Technology Management Dimensions

Variable	N	Range	Min	Max	Mean		Std. Deviation	Variance	Skewness		Kurtosis	
					Statistic	Std Error			Statistic	Std Error	Statistic	Std Error
A11	84	4.00	1.00	5.00	3.2857	.1520	1.3934	1.941	-.146	.263	-1.280	.520
A12	84	4.00	1.00	5.00	3.0476	.1208	1.1075	1.227	.013	.263	-.595	.520
A21	84	4.00	1.00	5.00	3.8333	.1332	1.2206	1.490	-.772	.263	-.209	.520
A22	84	4.00	1.00	5.00	3.9405	.1294	1.1858	1.406	-1.126	.263	.703	.520
A23	84	4.00	1.00	5.00	3.2500	.1406	1.2883	1.660	-.656	.263	-.739	.520
A24	84	4.00	1.00	5.00	3.1905	.1519	1.3925	1.939	-.131	.263	-1.353	.520
A25	84	4.00	1.00	5.00	3.7143	.1204	1.1039	1.219	-.563	.263	-.602	.520
A26	84	4.00	1.00	5.00	3.5714	.1440	1.3198	1.742	-.416	.263	-1.075	.520
A27	84	4.00	1.00	5.00	3.6429	.1252	1.1475	1.317	-.777	.263	.169	.520
A28	84	4.00	1.00	5.00	3.3214	.1439	1.3186	1.739	-.134	.263	-1.112	.520
A29	84	4.00	1.00	5.00	3.4167	.1439	1.3191	1.740	-.299	.263	-.841	.520
A30	84	4.00	1.00	5.00	3.1667	.1243	1.1389	1.297	-.085	.263	-.411	.520

The largest standard deviation is 1.39 from variables A11 and A24 and the smallest is 1.10 for variables A12 and A25. The skewness measure obtained for the technology management variables indicates that all of the variables, except variable A12 have negatively skewed distributions. Variable A22 falls outside the -1 range, which indicates a substantially skewed distribution. Finally, the kurtosis values obtained for eight of the variables indicate relatively flat distributions as shown in Table 2.

Descriptive Statistics: Company Performance Dimensions

The descriptive statistics of central tendency and measures of variability for the company performance dimensions are shown for variables B31 – B36 in Table 3.

Table 3: Descriptive Statistics - Company Performance Dimensions

Variable	N	Range	Min	Max	Mean Statistic	Std Deviation	Median	Mode	Skewness		Kurtosis	
									Statistic	Std Error	Statistic	Std Error
B31	84	5.00	1.00	6.00	2.9167	1.4579	3.00	2.00	.483	.263	-.858	.520
B32	84	5.00	1.00	6.00	2.7143	1.4106	3.00	1.00	.394	.263	-.792	.520
B33	84	5.00	1.00	6.00	2.2024	1.4790	2.00	1.00	1.084	.263	-.074	.520
B34	84	5.00	1.00	6.00	2.0238	1.2319	2.00	1.00	1.142	.263	.337	.520
B35	84	14.00	.00	14.00	2.4524	3.4165	.00	.00	1.316	.263	.872	.520
B36	84	62.00	-15.00	47.00	21.2381	12.3255	22.50	Multiple	-.548	.263	.118	.520

No missing values (N) were encountered with the data capturing process. The range for variables B31 – B34 is 5. The values assigned to this set of responses, run from 1 through 6 and, therefore, form an ordinal scale. However, variables B35 – B36 conforms to all the properties of the previously mentioned scales. These quantified responses form a ratio scale, which is defined as a set of numbers in which the ratios between numbers can be meaningfully interpreted (Parasuraman, Grewal, & Krishnan, 2007).

Two measures of central tendency are meaningful for the ordinal-scaled responses (B31 – B34):

- the mode as a number depicting the "middle" position in the range of responses; and
- the median, that is, the category in which the 50th percentile response falls when all responses are arranged from lowest to highest (or vice versa).

Referring to Table 3, variable B31 realised a mode of 2 (10 – 24%) for the percentage of sales over the last three years, due to new products. The percentage of innovation projects that earned a profit over the last three years (variable B32) corresponds to the response option (1) of less than 10%. The same mode applies to variable B33 (innovations as new-to-the-world breakthroughs) and B34 (R&D expenditure as a percentage of sales) for a rank order of less than 10%. The quantified responses to variables B35 and B36 are classified as metric data on the ratio scale.

The mean for the three-year-average number of patents registered (variable B35) per year, is 2.45 patents, with a high standard deviation of 3.42. However, the most frequently recurring response (mode) was 0 patents reported by respondents.

The mean for the company's three-year-average return on assets (variable B36) is 21.24%. Multiple modes have been calculated for variable B36 and for that reason, no mode is indicated. If the calculated values of skewness and kurtosis exceed a critical value, then the distribution is non-normal. A value exceeding ±2.58 indicates that the assumption about the normality of the distribution at the .01 probability level can be rejected. At the .05 error level, the critical value is ±1.96. All the above mentioned variables (A1 – B36) are within the limits of the critical values, thus indicating normality (Hair, Black, Babin, & Anderson, 2010).

Additional Descriptive Statistics

The increasing emphasis on knowledge acquisition and assimilation, is forcing companies to focus on methods to improve their effectiveness in technology management. The respondents were asked to select the primary form of R&D used in their companies for knowledge acquisition or assimilation. These responses are for variable B39, which are revealed in Table 4, relating to the acquisition and assimilation methods of technology.

Table 4: Technology Acquisition and Assimilation

Variable B39	Frequency	Percent	Valid Percent	Cumulative Percent
Centralised laboratories	19	22.6	22.6	22.6
Decentralised laboratories	22	26.2	26.2	48.8
Internal market	12	14.3	14.3	63.1
Contract	9	10.7	10.7	73.8
Collaborative	7	8.3	8.3	82.1
Consortium	9	10.7	10.7	92.9
Other	6	7.1	7.1	100.0
Total	84	100.0	100.0	

Almost 50% of the respondents have indicated that the principal form of R&D applied for technology acquisition and assimilation are through their own laboratories. Twenty-three percent of these laboratories constituted centralised laboratories, whereas the remaining 26% comprised decentralised laboratories. Twelve of the respondents selected the internal market method as primary means for R&D. This relates to the establishment of a functional cost centre, where each strategic business unit (SBU) pays for any R&D services required. The remaining 31 responses are spread out among contract, collaborative, consortium and other methods of technology acquisition and assimilation.

These and the other previously discussed responses are displayed in Figure 1.

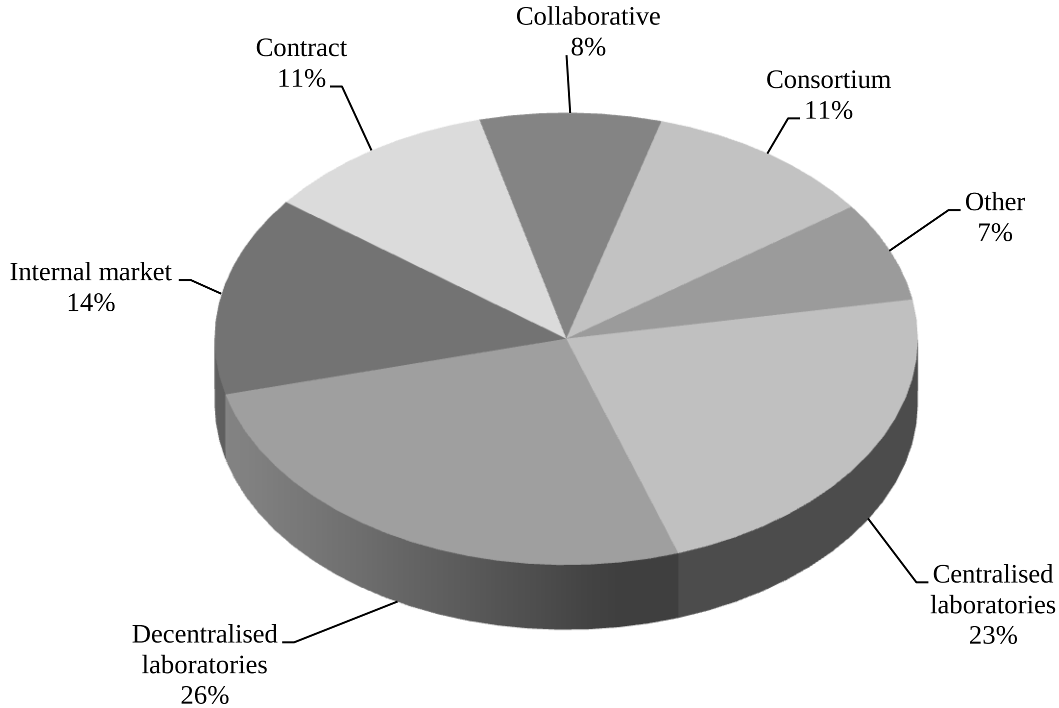

Figure 1: Technology Acquisition and Assimilation

Respondents were also asked to describe the technology transfer mode (e.g., licensing, hiring of skilled people, etc.) that is implemented in their companies or divisions. These responses were classified according to sixteen pre-defined transfer modes (see Figure 2). Seventy percent of the responses are classified in only three response option categories. From the 84 respondents that have indicated their technology transfer mode; twenty-five have no technology transfer mode (30%); twenty-one uses licensing for technology transfer (25%); and twelve are exchanging scientific and technical personnel for technology transfer (14%). The remaining 58 responses have been spread among the other technology transfer modes at the 0 to 4.8% level.

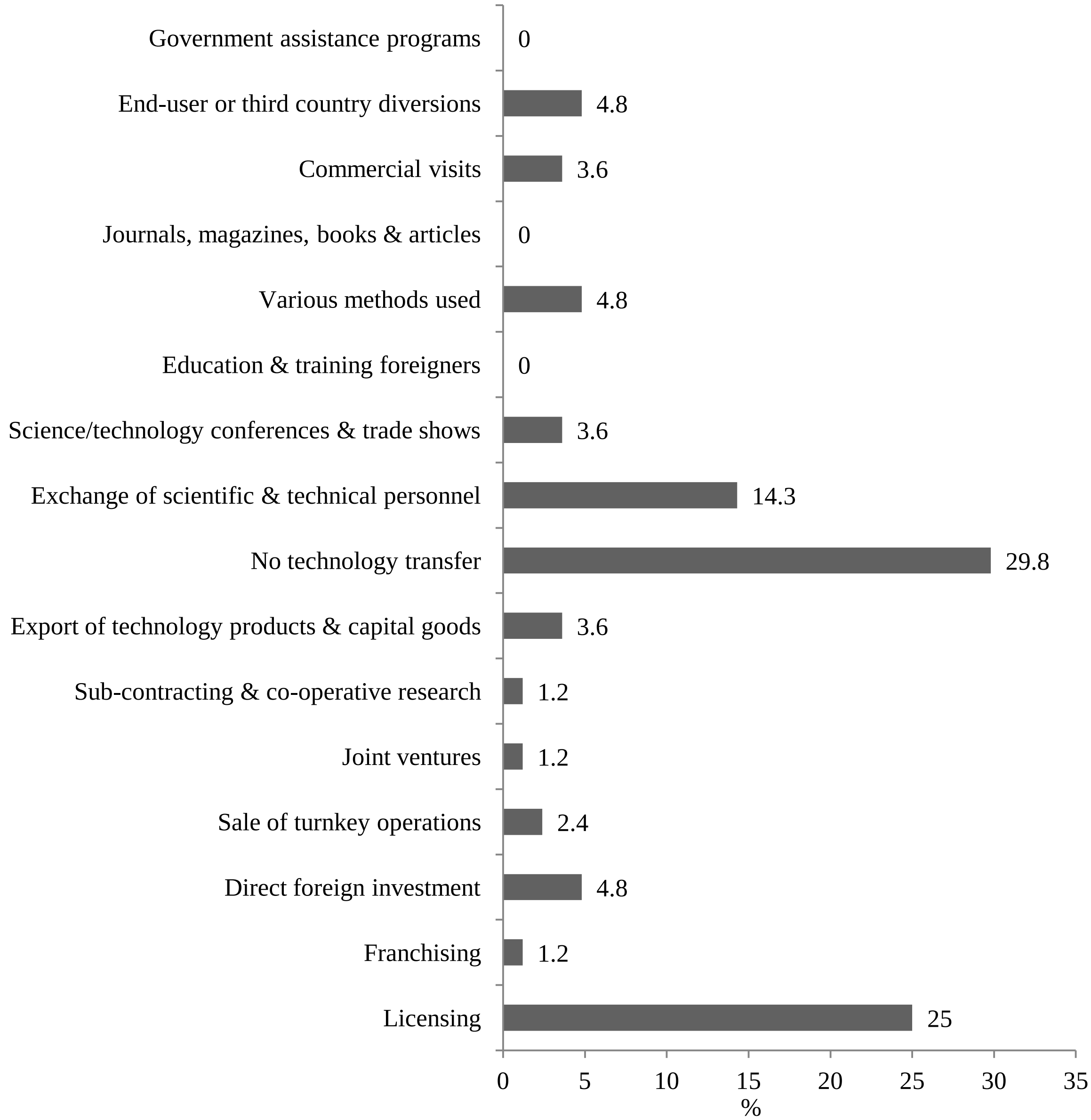

Figure 2: Technology Transfer Modes

Factor Analysis: Technology Management

The twelve technology management variables (A11, A12, and A21 – A30), were factor-analysed by using the principal axis factoring method. Then using the latent root criterion, three factors were extracted on the basis of their Eigenvalues being greater than 1. Together they accounted for 78.81% of the variation in the data. The factors were rotated by using the Varimax rotation method. The correlation matrix for the twelve management variables was reviewed to confirm the existence of a substantial number of correlations, which indicates the existence of common factors. The technology management variables had correlations greater than .26 and more than 60% of the matrix elements were greater than .50. Bartlett's test of sphericity confirmed, that the correlation matrix was not an identity matrix. The Kaiser-Meyer-Olsen (KMO) measure as sampling adequacy was .756, which Hair et al. (1998) characterised as "middling." This is also defined as an adequate measure, indicating that the degree of correlation between the unique factors was low. The anti-image covariance matrix contained few elements with values greater than 0.9, again confirming the applicability of factor analysis.

The number of factors to be extracted was set at three, based on Eigenvalues greater than 1. However, the scree test indicates, that four factors would be retained. In combining these two criteria, three factors were eventually retained for further analysis, because of the very low Eigenvalue (.664) for the fourth factor.

The Chi-square statistic was 922.647 with 66 degrees of freedom, which is significant at the .000 level. The reduced set of variables collectively meets the necessary threshold of sampling adequacy and thus the fundamental requirements for factor analysis. The reproduced correlation matrix contained 12 residual values (18%) greater than .05, indicating that the model fits the data. The rotated technology management factor loadings are contained in Table 5. As a reminder, each survey respondent was asked to report on the importance of each of the variables to his or her company relative to major competitors. The heaviest factor loading for each variable is formatted in bold font style.

Table 5: Rotated Technology Management Factor Matrix

Variable	Variable Description	Factor 1	Factor 2	Factor 3
A22	Awareness of technologies	**.954**	.165	.054
A21	Awareness of technology sources	**.904**	.225	-.018
A25	Using formal product plans	**.758**	.466	.092
A24	External technology acquisition	**.729**	.319	-.042
A23	Internal technology acquisition	**.727**	.366	.103
A26	Using formal technology plans	**.657**	.389	-.101
A27	Integrating R&D operations	.350	**.821**	.069
A29	High level of R&D investment	.329	**.732**	.121
A30	External funding for R&D	.160	**.674**	-.193
A28	Evaluating & rewarding R&D personnel	.370	**.662**	-.039
A11	Technology and manufacturing	-.004	-.133	**.950**
A12	Technology and production flexibility	.036	.075	**.856**

All of the primary factor loadings used in the factor interpretation exceeded .50 in value. According to Hair et al. (2010), factor loadings greater than ±.30 are considered to meet the minimal level; loadings of ±.40 are considered important; and if the loadings are ±.50 or greater, they are considered more important. Considering the factor loadings, the rotated factors are interpreted below and visually displayed in Figure 3.

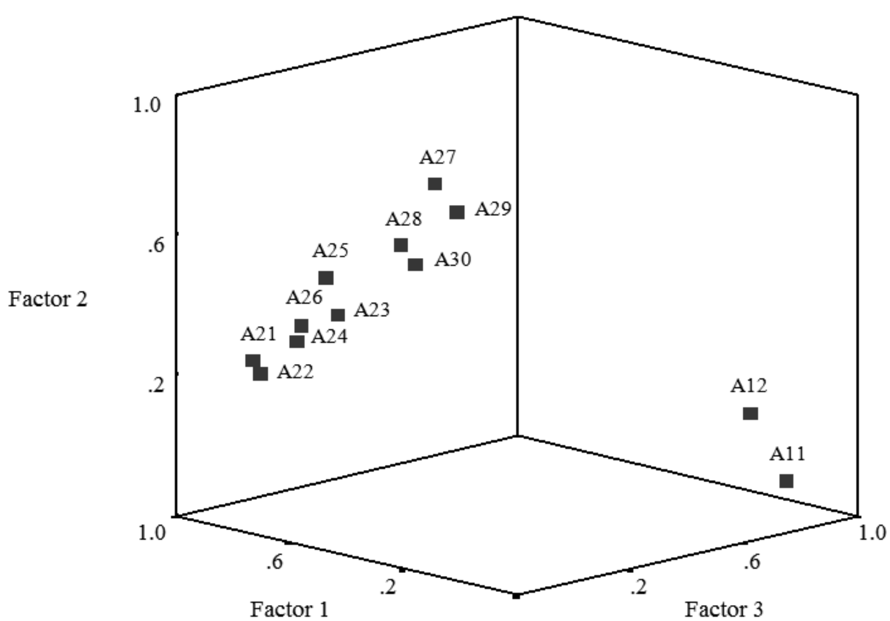

Figure 3: Rotated Technology Management Factor Plot

1. R&D Commitment – The Eigenvalue of the first factor was 5.729. The technology awareness variables (A21-A22), technology acquisition variables (A23-A24) and the technology and product planning variables (A25-A26) loaded heavily on this factor. Taken together, these patterns of factor loadings clearly reflect the aggressiveness of a company's R&D commitment.
2. Control Market Planning – The Eigenvalue of the second factor was 2.889. The R&D organisation and management variables (A27-A28) and R&D investment variables (A29-A30) loaded heavily on this factor, indicating the degree of researcher empowerment, researcher rewards and integration of R&D with the business units.
3. Process Management – The Eigenvalue of the third factor was 1.806. The manufacturing and process technology variables (A11-A12) both loaded heavily on this factor. This indicates that the underlying factor relates to the company's manufacturing and technology processes.

Factor Analysis: Company Performance

The methodology for factor analysing the dependent variables, was similar to that used for the previous sections. The six company performance variables (B31 – B36) were factor-analysed by using the principal axis factoring method. Then, using the latent root criterion, two factors were extracted on the basis of their Eigenvalues being greater than 1. Together they accounted for 75.80% of the variation in the data. The factors were rotated by using Varimax rotation method. The same number of methods was used to determine the appropriateness of a factor-analytic model for this analysis.

The correlation matrix for the six company performance variables was reviewed to confirm the existence of a substantial number of correlations, which indicates the existence of common factors. All the variables had correlations greater than .16 and more than 40% of the matrix elements were greater than .50. Bartlett's test of sphericity confirmed, that the correlation matrix was not an identity matrix. The Kaiser-Meyer-Olsen (KMO) measure as sampling adequacy was .791, which Hair et al. (2010) characterised as "middling." This is also defined as an adequate measure, indicating that the degree of correlation between the unique factors was low. The anti-image covariance matrix contained no elements with values greater than 0.9, again confirming the applicability of factor analysis.

Based on the Kaiser criterion of selecting factors with Eigenvalues greater than 1, the number of factors to be extracted, were set at two. However, the scree test indicates, that three factors would be retained. In combining these two criteria, two factors were eventually retained for further analysis, because of the very low Eigenvalue (.538) for the third factor. The Chi-square statistic was 235.832 with 15 degrees of freedom, which is significant at the .000 level. The reduced set of variables collectively meets the necessary threshold of sampling adequacy and thus the fundamental requirements for factor analysis.

The final statistics showed, that 75.80% of the variance was explained by the two factors. The reproduced correlation matrix contained 3 residual values (20%) greater than .05, indicating that the model fits the data. The rotated company performance factor loadings are contained in Table 6. The heaviest factor loading for each variable is formatted in bold font style.

Table 6: Rotated Company Performance Factor Matrix

Variable	Variable Description	Factor 1	Factor 2
B32	Efficiency of innovation project management	**.841**	.308
B33	Impact of the innovations	**.797**	.213
B31	New product contribution to sales	**.773**	.188
B34	R&D expenditure	**.756**	.123
B35	Patents registered	.089	**.762**
B36	Return on assets	.308	**.619**

As a reminder, each respondent was asked to respond to the following questions.

B31 – Approximately what percentage of sales over the last three years was due to new products?
B32 – Approximately what percentage of innovation projects over the last three years earned a profit?

B33 – Approximately what percentage of innovations over the last three years could be considered new-to-the-world breakthroughs?
B34 – What is your three-year-average R&D expenditure as a percentage of sales?
B35 – What is your three-year-average number of patents registered per year?
B36 – What is your company or division's three-year-average ROA?

All of the primary factor loadings used in the factor interpretation, exceeded .50 in value. Considering the factor loadings, the rotated factors are interpreted below and visually displayed in Figure 4.

1. Input Performance – The conceptual definition for this factor is the extent to which the R&D manager or other top manager perceives the innovation management organisation has achieved its desired objectives over the last three years. The Eigenvalue of the first factor was 3.167. The four input variables (B31 – B34) loaded heavily on this factor. Taken together, this pattern of factor loadings clearly reflects the effectiveness of the innovation management organisation (IMO).
2. Output Performance – This factor represents the performance of the company where (1) patent information was used to measure R&D activities and (2) return on assets (ROA) was used to measure company financial performance. The Eigenvalue of the second factor was 1.381. The patent's registered variable (B35) and the return on assets variable (B36) loaded heavily on this factor, indicating the degree of fit for this performance measure.

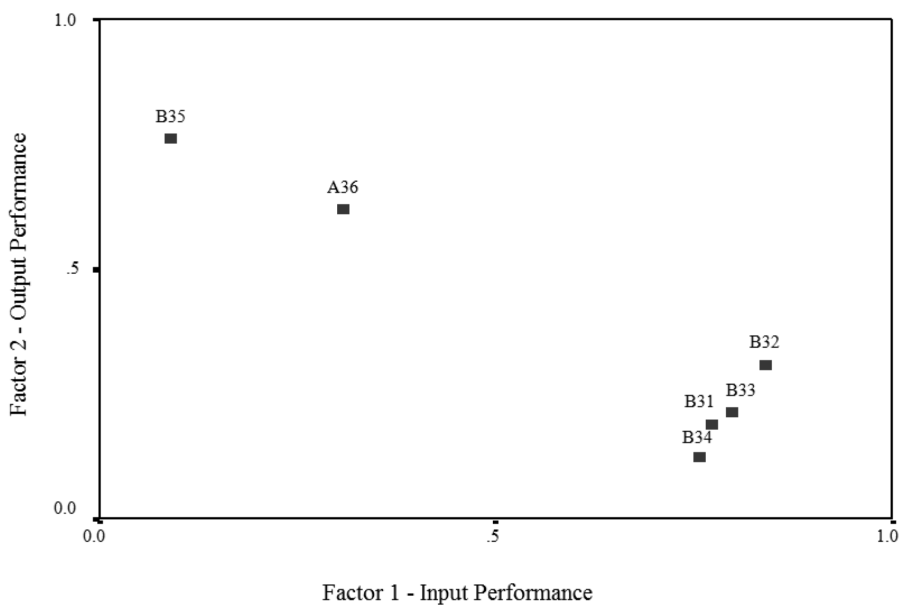

Figure 4: Rotated Company Performance Factor Plot

Reliability and Validity

The data analysis proceeds by evaluating the survey responses according to the four dimensions for validity and reliability. The summated scales of the study provide two specific benefits. First, it provides a means of overcoming the measurement error inherent in all measured variables. A second benefit of the summated scale is its ability to represent the multiple aspects of a concept in a single measure; e.g., the technology focus factor. However, four issues basic to the construction of any summated scale must be addressed before applying them (Hair et al., 2010).

Content validity is the first issue, which subjectively assesses the correspondence between individual items and the concept through ratings by expert judges, pre-tests and other means. Content validity of the questions was obtained from the pilot study and the cognitive confirmation from the five technology experts. The second issue, which is validated by the high factor loadings (greater than 0.5) of the extracted factors, concerns the test of uni-dimensionality. According to Anderson, Gerbing, and Hunter (1987), each summated scale should consist of items loading highly on a single factor.

The third issue concerns the degree of consistency between multiple measurements of a variable, known as reliability. The consistency of the survey data was assessed by using Cronbach's coefficient alpha, which measure the consistency of the entire scale. The Cronbach alpha computations for the five extracted factors are shown in Table 7. For the R&D commitment it is .9367; for the control market planning it is .8601; for the process management it is .8826, and for the input performance it is .8887. These high values indicate a high degree of data stability.

Table 7: Reliability Analysis

Variable	Scale mean if item deleted	Scale variance if item deleted	Corrected item total correlation	Alpha if item deleted	Alpha
R&D Commitment (R&D)					
A21	17.6667	29.9598	.8716	.9177	**.9367**
A22	17.5595	30.1289	.8882	.9161	
A23	18.2500	30.4307	.7744	.9298	
A24	18.3095	29.3247	.7845	.9296	
A25	17.7857	31.3993	.8470	.9221	
A26	17.9286	30.5972	.7368	.9349	
Control Market Planning (CMP)					
A27	9.9048	10.0390	.7991	.7864	**.8601**
A28	10.2262	9.6952	.6981	.8264	
A29	10.1310	9.4646	.7346	.8102	
A30	10.3810	11.2266	.6083	.8593	
Process Management (PM)					
A11	3.0476	1.2266	.8108	-	**.8826**
A12	3.2857	1.9415	.8108	-	
Input Performance (InP)					
B31	6.9405	13.3820	.7446	.8617	**.8887**
B32	7.1429	13.0637	.8234	.8305	
B33	7.6548	13.1685	.7540	.8584	
B34	7.8333	15.1044	.7130	.8741	
Output Performance (OutP)					
B35	21.2381	151.9185	.5015	-	**.4104**
B36	2.4524	11.6724	.5015	-	

Looking at Table 7, it is evident that the output performance factor coefficient alpha is only .4104. However, the data accuracy aspect of reliability can be tested by comparing the test data with external criteria that measure the same variable. In this study the self-reported company return on asset variable (B36) was compared with published financial data from various sources (I-Net Bridge, company reports, etc.). Sixty-seven of 84 respondents correctly reported the return on asset (ROA) category. Fourteen cases exaggerated their ROA by one category and the remaining three cases diminished their ROA by one category. Three Chi-square-based measures of association were calculated; i.e., the phi coefficient, the coefficient of contingency and Cramer's V. Their respective values were 1.26, .63, and .78. All were significant at the .00000 level (rounded to the fifth decimal place), indicating a strong relation between the reported and actual ROA data. These factors point to an acceptably high degree of data reliability.

The fourth and final dimension for validity and reliability concerns construct validity. Construct validity is concerned with the question of what the research instrument is, in fact, measuring. Common factor analysis is one of the methods of analysing construct validity. The factor analysis found relatively high degrees of communality among the variables. Most of the dimension variables have communalities greater than 0.5. The clear patterns of the factor loadings on the variables further validated the content and process constructs.

Multiple Regression Analysis

To ascertain the relative importance of the factors in explaining the variation in the dependent variables, multiple regression analysis was used to analyse the relationship between the dependent variables and independent variables. The objective of multiple regression analysis is to use the independent variables (three factors) whose values are known to predict the single dependent values (two performance factors). The Pearson r-correlations were calculated to find the strength and direction of the relationships between the factors and the performance dimensions. By using p-values, it was possible to distinguish between the levels of significance. From Table 8 the null-hypothesis was rejected ($p < 0.05$ or $p < 0.01$) for all the factor correlations except for the Process Management factor ($p > 0.05$ or $p > 0.01$).

Table 8: Correlation Matrix

		R&D Commitment	Control Market Planning	Process Management	Input Performance	Output Performance
R&D Commitment	Pearson Correlation	1.000	.638*	.012	.579*	.710*
	Sig. (2-tailed)	.	.000	.917	.000	.000
	N	84	84	84	84	84
Control Market Planning	Pearson Correlation	.638*	1.000	-.039	.731*	.382*
	Sig. (2-tailed)	.000	.	.721	.000	.000
	N	84	84	84	84	84
Process Management	Pearson Correlation	.012	-.039	1.000	-.195	-.030
	Sig. (2-tailed)	.917	.721	.	.075	.788
	N	84	84	84	84	84
Input Performance	Pearson Correlation	.579*	.731*	-.195	1.000	.435*
	Sig. (2-tailed)	.000	.000	.075	.	.000
	N	84	84	84	84	84
Output Performance	Pearson Correlation	.710*	.382*	-.030	.435*	1.000
	Sig. (2-tailed)	.000	.000	.788	.000	.
	N	84	84	84	84	84

*. Correlation is significant at the 0.01 level (2-tailed).

It is apparent that both the R&D Commitment and Control Market Planning factors have a significant positive effect on Input and Output Performance.

The level of relationship (R^2 or Rsq) that can be detected reliably with the proposed regression analysis was calculated to indicate the percentage of total variation of the Input Performance factor (InP). The Control Market Planning (Rsq = 0.5344) factor explains 53% of the total variation of the Input Performance factor. It means that the degree of researcher empowerment, researcher rewards, the integration of R&D with the business units and the level of R&D investment, determine the variation of the company's contribution to sales, efficiency of innovation project management, impact of the innovations, and R&D expenditure. The R&D Commitment factor (Rsq = 0.3352) explains 34% of the total variation of the Input Performance factor. It means that the aggressiveness of a company's R&D investment and the emphasis it places on integrating R&D operations, determine the variation of the company's contribution to sales, efficiency of innovation project management, impact of the innovations and R&D expenditure. The Process Management (Rsq = 0.0380) factor explains 4% of the total variation of the Input Performance factor. It means, that the emphasis a company places on manufacturing flexibility and technology processes, determines the variation of the company's contribution to sales, efficiency of innovation project management, impact of the innovations, and R&D expenditure.

The level of relationship (R^2 or Rsq) that can be detected reliably with the proposed regression analysis was calculated for the creation of the Output Performance model. The Control Market Planning (Rsq = 0.1459) factor explains 15% of the total variation of the Output Performance factor. It means that the degree of researcher empowerment, researcher rewards, the integration of R&D with the business units, and the level of R&D investment, determine the variation of the company's contribution to R&D activities (patents registered) and the company's efficiency in using its assets (return on assets). The R&D Commitment (Rsq = 0.5041) factor explains 50% of the total variation of the Output Performance factor. It means, that the aggressiveness of a company's R&D

investment and the emphasis it places on integrating R&D operations, determine the variation of the company's contribution to R&D activities (patents registered) and the company's efficiency in using its assets (return on assets). The Process Management (Rsq = 0.0900) factor explains only 0.1% of the total variation of the Output Performance factor. It means, that the emphasis a company places on manufacturing flexibility and technology processes, have relatively no impact on the variation of the company's contribution to R&D activities (patents registered), and the company's efficiency in using its assets (return on assets).

LIMITATIONS ON THE RESEARCH

This study confines its focus to the effects of technology policy on company performance. In so doing, a number of other factors which affect company performance are omitted; e.g., marketing strategy, financial structure, culture, human resources, etc. The study was also restricted to South African listed companies in the Industrial Consumer sector on the Johannesburg Stock Exchange. Finally, the study is also limited to Return on Assets (ROA) as a financial measure of company performance.

RECOMMENDATIONS

The role of the top manager in technology intensive industries has become much more multidimensional and multi-disciplinary. This is recognized by assigning both the R&D Commitment and Control Market Planning factors to the top manager and top management team functions. These two functions are responsible for the formal technology policy within the company, with the objective to manage technical risk, increasing the sophistication of technology components utilised and the number of technologies in which the company maintains competence. Furthermore, they should be conscientious with encouraging researcher empowerment, the vast integration of R&D with the company's business units and a high level of R&D investment.

Another requirement of the innovation management organisation (IMO) is frequent new product introductions and frequent product upgrades, with the emphasis placed on expanding existing product lines and by introducing improved versions of existing products. The activities associated with this Product Development Intensity factor, are contained within the R&D, production, and sales and marketing functions; the latter function being primarily responsible for interfacing between the company and the marketplace for introducing new or upgraded products.

The R&D Commitment factor reflects the aggressiveness of a company's R&D commitment and the emphasis it places on integrating R&D operations. It mirrors the organisational issues and the processes involved in developing and implementing a strategic approach to technology. Companies, who have loaded heavily on this factor, emphasise acquiring information about emerging technological threats, opportunities, and sources. Furthermore, these companies express the need for acquiring technology from internal R&D activities and/or external sources. The majority of the respondents have indicated, that the principal form of R&D applied for technology acquisition and assimilation, are their own laboratories. This conforms to similar findings, which suggest a growing centralisation of R&D among leading high-technology companies. Furthermore, these companies place a significant emphasis on formal product plans that are market-driven and formal technology plans that are product-driven.

The Control Market Planning factor indicates the degree of researcher empowerment, researcher rewards, the integration of R&D with the business units and the level of R&D investment. It, therefore, signifies the propensity of a company to integrate R&D operations into product division operations and to manage R&D personnel based on R&D project success (Garnett & Pelser, 2007). The innovation management organisation (IMO) is responsible for developing new products and technologies in response to future threats and opportunities. Hence, science and technology from the external environment are combined with the company's in-house skills, knowledge, and competencies to develop new products and technologies. Companies that have loaded high on this factor are displaying characteristics of a typical IMO. Furthermore, these companies commit high levels of investment to their R&D activities relative to sales and place emphasis on achieving financial leverage for R&D investments through external funding. These investments determine the technical outputs of a company, such as patents and new product and process technologies.

The domain of innovation management includes both the R&D and strategic management functions. R&D consists of those activities and responsibilities ranging from understanding progressive technology to generating ideas to developing new products and technologies as underpinned by the R&D Commitment factor. Thus the collaboration between the R&D Commitment factor with the strategic management function activate the innovation process by identifying new and/or different combinations of market technology factors which will create the competitive advantage necessary for sustaining industry leadership.

CONCLUSION

The main purpose of this study was to investigate technology management in widespread use in technology intensive industries and to explore their relationship to company performance. In essence, the following two research questions were addressed in this study.

1. What is the prevalent technology management dimensions being employed by South African companies in technology intensive industries?
2. What relationships can be observed between the technology management dimensions and company performance?

Question one was addressed through factor analysing the technology management dimensions obtained from the survey. The second question was answered by regression analysis. The two distinct technology management factors obtained with the analysis were proved to positively influence the company performance dimensions and were classified as R&D Commitment and Control Market Planning factors.

Strategic management is inter alia a process of managing a company's relationship with the environment. As a matter of strategy, a product should be matched with that segment of the market in which it is in all probability most likely to succeed (Prinsloo, Groenewald, & Pelser, 2014, p. 130). A critical concern of this discipline is optimising returns to the company's stakeholders over the long term. This means sustaining performance by balancing strategic investments in technology with short-term profitability. The present study makes a significant contribution to the field of strategic management research by integrating the dimensions of several previous studies, to derive a more comprehensive taxonomy of technology management archetypes. It also derives a broader set of dimensions for use in strategic management research. The results show that technology management choices can significantly affect company performance. It thereby indicates which of the underlying dimensions have the strongest relationship with company performance.

There are many directions in which this research can be extended in both depth and breadth. For example, the number of companies surveyed, could be expanded (e.g., from local to international, listed to unlisted, high-technology to low-technology) to allow for greater control of the many exogenous variables (e.g., size, stage of industry life cycle, degree of alignment between the company's strategies and the environment), which affect the relationship between strategy and company performance.

From an industry perspective, the greatest significance of these findings may be that they accentuate the importance technology management in developing and implementing a strategic approach to technology. This study has expanded on the identified technology process dimensions and has highlighted the link between technology strategy and technology management through different measures of performance.

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REFERENCES

1. Anderson, J. C., Gerbing, D. W., & Hunter, J. E. (1987). On the assessment of unidimensional measurement: Internal and external consistency and overall consistency criteria. *Journal of Marketing Research, 24,* 432-437.
2. Beukes, J., Prinsloo, J. J., & Pelser, T. G. (2013). Service expectations from high- and low-volume customers in the alcoholic beverage industry. *Acta Commercii, 13*(1), Art. #172, 8 pages. http://dx.doi.org/10.4102/ac.v13i1.172
3. Brockhoff, K. (1998). Technology management as part of strategic planning: Some empirical results. *R&D Management, 28*(3), 129-138.
4. Brush, C. G., & Vanderwerf, P. A. (1992). A comparison of methods and sources for obtaining estimates of new venture performance. *Journal of Business Venturing, 7*(2), 157-170.
5. Clark, K., Ford, D., & Saren, M. (1989). Company technology strategy. *R&D Management, 19*(3), 215-229.
6. Cool, K. O., & Schendel, D. E. (1987). Strategic group formation and performance: The case of the U.S. pharmaceutical Industry, 1963-1982. *Management Science, 33*(9), 1102-1124.
7. Cooper, A. C. (1979). Strategic management: new ventures and small business. In D. E. Schendel & C. W. Hofer (eds.), *Strategic management: A new view of business policy and planning*. Boston, MA: Little Brown.
8. Dvir, D., Segev, E., & Shenhar, A. (1993). Technology’s varying impact on the success of strategic business units with the Miles and Snow typology. *Strategic Management Journal, 14*(2), 155-162.
9. Eng, T., & Ozdemir, S. (2014). International R&D partnerships and intrafirm R&D–marketing–production integration of manufacturing firms in emerging economies. *Industrial Marketing Management, 43*(1), 32-44.
10. Ensminger, D. C., Surry, D. W., Porter, B. E., & Wright, D. (2004). Factors contributing to the successful implementation of technology innovations. *Educational Technology & Society, 7*(3), 61-72.
11. Fiegenbaum, A., & Thomas, H. (1990). Strategic groups and performance: The US insurance industry, 1970-1984. *Strategic Management Journal, 11*(3), 197-216.
12. Garnett, A., & Pelser, T. G. (2007). Organisational barriers to creativity in South African higher education institutions. *South African Journal of Higher Education, 21*(1), 50-67.
13. Galbraith, C., & Schendel, D. (1983). An empirical analysis of strategy types. *Strategic Management Journal, 4*(2), 153-173.
14. Granstrand, O., Bohlin, E., Oskarsson, C., & Sjoberg, N. (1992). External technology acquisition in large multi-technology corporations. *R&D Management, 22*(2), 111-133.
15. Hair, J. F. Jnr., Black, W. C, Babin, B. J., & Anderson, R. E. (2010). *Multivariate data analysis: A global perspective* (7th ed.). Upper Saddle River: Pearson Prentice Hall.
16. Halachmi, A., & Bouckaert, G. (1994). Organisational technology and organizational design. *Work Study, 43*(3), 19-25.
17. Hansen, A. (2010). Nonfinancial performance measures, externalities and target setting: a comparative case study of resolutions through planning. *Management Accounting Research, 21*(1), 17-39.
18. Hamel, G., & Prahalad, C. K. (2006). The core competence of the corporation strategic learning in a knowledge economy. In D. Hahn & B. Taylor (eds.), *Strategische Unternehmungsplanung — Strategische Unternehmungsführung*. Berlin, Heidelberg: Springer.
19. Harmon, P., & Davenport, T. (2007). *Business process change* (2nd ed.). Burlington, Massachusetts: Morgan Kaufmann.
20. Human Sciences Research Council. (2014). National survey of research & experimental development (2011/12 Fiscal Year): high-level key results. Pretoria: HSRC Library.
21. Lee, S., Yoon, B., Lee, C., & Park, J. (2009). Business planning based on technological capabilities: Patent analysis for technology-driven roadmapping. *Technological Forecasting and Social Change, 76*(6), 769-786.
22. Lussier, R. N. (1995). A non financial business success versus failure prediction model for young firms. *Journal of Small Business Management, 33*(1), 8-20.
23. Maidique, M. A., & Patch, P. (1988). Corporate strategy and technological policy. In M. L. Tushman & W. L. Moore (eds.), *Readings in the management of innovation* (2nd ed.). Cambridge, MA: Ballinger.

24. Miles, R. E., & Snow, C. C. (1978). *Organisational strategy, structure and process*. New York: McGraw-Hill.
25. Miller, A. (1988). A taxonomy of technological settings with related strategies and performance levels. *Strategic Management Journal*, *9*(3), 239-254.
26. Miller, D., & Friesen, F. (1977). Archetypes of strategy formulation. *Management Science, 24*(9), 921-933.
27. Miller, D., & Toulouse, J. M. (1986). Strategy, structure, CEO personality and performance in small firms. *American Journal of Small Business*, *10*(3), 47-62.
28. Murphy, G. B., Trailer, J. M., & Hill, R. C. (1996). Measuring performance in entrepreneurship research. *Journal of Business Research*, *36*(1), 15-23.
29. Nambisan, S., & Wilemon, D. (2003). A global study of graduate management of technology programs. *Technovation*, *23*(12), 949-962.
30. Panagiotou, G. (2007). Reference theory: strategic groups and competitive benchmarking. *Management Decision, 45*(10), 1595-1621.
31. Pandian, J. R, Thomas, H. Furrer, O., & Bogner, W. C. (2006). Performance differences across strategic groups: an examination of financial market-based performance measures. *Strategic Change, 15*(6), 373-383.
32. Parasuraman, A., Grewal, D., & Krishnan, R. (2007). *Marketing research* (2nd ed.). Boston, MA: Houghton Mifflin Harcourt.
33. Pelser, T. G. (2001). *A strategic management taxonomy of technology and innovation*. (Unpublished PhD thesis). Potchefstroom: Potchefstroomse Universiteit vir Christelike Hoër Onderwys.
34. Pelser, T. G. (2014a). Sustaining industry leadership through technology strategy dimensions. *Journal of Applied Business Research, 30*(3), 763-782.
35. Pelser, T. G. (2014b). The influence of technology strategies and their link to company performance. *Mediterranean Journal of Social Sciences, 5*(9), 238-247.
36. Pelser, T. G. (2014c). The affect of innovation strategies and their connect to company performance. *Mediterranean Journal of Social Sciences*, *5*(9), 60-68.
37. Pelser, T. G. (2014d). Sustaining industry leadership through innovation strategy archetypes. *International Business & Economics Research Journal, 13*(4) (no page numbers yet).
38. Pérez-Luñoa, A., Wiklundb, J., & Cabrera, R. A. (2011). The dual nature of innovative activity: How entrepreneurial orientation influences innovation generation and adoption. *Journal of Business Venturing, 26*(5), 555–571.
39. Prinsloo, J. J., Groenewald, A., & Pelser, T. G. (2014). Market positioning of branded meat products: A case of the feedlot industry in South Africa. *Mediterranean Journal of Social Sciences*, *5*(1), 129-135.
40. Sabidussi, A., Lokshin, B., de Leeuw, T., Duysters, G., Bremmers, H., & Omta, O. (2014). A comparative perspective on external technology sourcing modalities: The role of synergies. *Journal of Engineering and Technology Management*, *33*, 18-31. http://dx.doi.org/10.1016/j.jengtecman.2014.02.00
41. Sapienza, H. J., Smith, K. G., & Gannon, M. J. (1988). Using subjective evaluations of organizational performance in small business research. *American Journal of Small Business*, *12*(3), 45-53.
42. Seaton, R., & Cordey-Hayes, M. (1993). The development and application of interactive models of industrial technology transfer. *Technovation, 13*(1), 45-53.
43. Snow, C. C., & Hrebiniak, L. G. (1980). Strategy, distinctive competence and organisational performance. *Administrative Science Quarterly*, *25*(2), 317-336.
44. Sohal, A. (1995). Assessing implementations: An empirical field study. *Proceedings of the 1995 European Conference on Management of Technology*. Birmingham, 469-484.
45. Somsuk, N., & Laosirihongthong, T. (2013). A fuzzy AHP to prioritize enabling factors for strategic management of university business incubators: Resource-based view. *Technological Forecasting and Social Change,* (volume/issue information not available yet). http://dx.doi.org/10.1016/j.techfore. 2013.08.007
46. Song, M., Zhao, Y. L., & Di Benedetto, C. A. (2013). Do perceived pioneering advantages lead to first-mover decisions? *Journal of Business Research*, *66*(8), 1143-1152.
47. Swann, K., & O'Keefe, W. D. (1990). Advanced manufacturing technology: investment decision process. *Management Decision*, *28*(3), 27-34.
48. Thongpapanl, N. (2012). The changing landscape of technology and innovation management: An updated ranking of journals in the field. *Technovation*, *32*(5), 257-271.

49. Trott, P. (1998). *Innovation management and new product development*. London: Financial Times.
50. Tsai, K., Hsieh, M., & Hultink, E. (2011). External technology acquisition and product innovativeness: The moderating roles of R&D investment and configurational context. *Journal of Engineering and Technology Management, 28*(3), 184-200.
51. Werther, W. B., Berman, E., & Vasconiellos, E. (1994). The future of technology management. *Organisational Dynamics, 22*(3), 20-32.
52. Zahra, S. A., & Covin, J. (1993). Business strategy, technology policy and firm performance. *Strategic Management Journal, 14*(6), 451-478.
53. Zahra, S. A., & Covin, J. (1994). The financial implications of fit between innovation types and sources and competitive strategy. *Journal of High Technology Management Research, 5*(2), 183-212.
54. Zahra, S. A., & Hayton, J. C. (2008). The effect of international venturing on firm performance: The moderating influence of absorptive capacity. *Journal of Business Venturing, 23*(2), 195-220.

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