Integrating technology and operations in a developing country context

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Abstract
The importance of technology to developing countries is widely recognised as they compete internationally and develop internally. Firms acquire technology by different means and from diverse sources, and they possess varying levels of competence. Since countries are at various stages of economic and technological development, prescriptive approaches to technology and operations integration are not appropriate. The paper discusses factors in the literature that affect the integration of technology and operations in developing countries. Country similarities and differences also play a role, so the study examines three developing countries: Brazil, India and South Africa. These countries are emerging from periods of regulation and have developed certain sectors of their economies. Empirical evidence is provided from a study of managers in South Africa who were asked to assess the important factors in technology integration, and to score the extent to which they can control these. Results from the study concur with the literature regarding the importance of a country's political stability and its policies towards new investment and infrastructure. Knowledge and understanding of technology are essential for successful integration in countries with insufficient skilled personnel, and where education levels are low.

Key words: technology, operations, integration, developing countries, Brazil, India, South Africa

Introduction

The literature recognises the role of technology in economic growth and development, and how it assists firms to survive in a competitive environment (Kumar and Jain, 2001). Developing countries are subject to the same global pressures as their developed counterparts, but are burdened by domestic conditions which place them at a significant, and perhaps, insurmountable disadvantage, as they struggle with new technology, inadequate intellectual capital, limited experience and insufficient organisational competence (Fleury, 1999). Developing countries need to acquire a technological base in order not to be subjugated to permanent dependence on imported technology. As regulatory and protective barriers are removed and new firms enter developing country markets, organisations face competition that is often incompatible with existing company cultures (Evaristo, 1998; Narayanan, 1998).

While a substantial body of literature covers technology transfer to developing countries, few studies have addressed the integration of new technology and operations. This paper aims to assess how competitive forces in developing countries drive organisations to integrate new technologies and operations. Firms acquire technology by different means and from a number of sources, organisations have varying levels of competence, and country characteristics play a role, so one set of factors cannot prescribe a single approach to technology and operations integration.

The paper reviews the technology and operations literature relating to developing countries, with specific reference to Brazil, India and South Africa. As countries exhibiting first and third world characteristics, they meet international standards in a number of sectors and have been the recipients of high-tech investments from developed economies (such as automobile plants, IT and telecommunications), but the majority of their inhabitants live in abject poverty.

For its empirical evidence the paper draws on a survey by the authors of more than 200 South African managers regarding their perceptions of technology integration. The managers were asked to list significant items in technology management, and to score their importance and the extent to which they could control them, both now and in 3 years' time. Using a methodology of Naudé et al (1990), the scores are plotted on an importance-control grid. Interviews were held with managers in order to understand and interpret the quantitative data. The study concludes with a discussion of the broader implications for managers in developing countries.

Technology integration in developing countries

Structural and political events have influenced the flow of technology to developing countries. When monopolies previously protected by legislation are deregulated or privatised, they are subject to competition from international companies with higher levels of technology, greater access to resources, and the ability to choose specific market segments. A deregulated monopoly is likely to have older technology, and a monopoly company culture, although it may potentially have the advantage of competitive intelligence and a better understanding of the capabilities, strategies and requirements of the stakeholders in that market (Evaristo, 1998).

The introduction of new technology in developing countries depends on political, technological and economic factors. Prochno and Corrêa (1995) claim that the turbulent environments prevailing in some developing countries call for different approaches from those in stable, developed countries. Firms seek political and economic stability, and domestic and international growth potential. For example, long-term planning in Brazil has been aggravated by high interest rates, high and unstable levels of inflation, and frequently changing government industrial policies, where "six months is long term planning in Brazil" (Prochno and Corrêa, 1995).

The adoption of new technology is a complex process of selecting and installing equipment to match strategic decisions and resource plans. The operational challenge is one of managing the emerging technology and beyond (Smit and Pistorius, 1998). Developing countries are obliged to meet global competition by expanding their infrastructure, training, cost reduction efforts, and through improvements in productivity. As technology, intellectual capital and knowledge assets are moved across boundaries by multinational companies, governments of developing countries and domestic firms are frequently bound by the power of the multinationals. Meanwhile firms in the developed world use their technology-based expertise to provide better quality and service, thereby gaining an even greater competitive lead through their global activities (Nagabhushana and Shah, 1999).

Fleury (1999: 552) identifies three stages of globalisation: deregulation of financial markets (financial globalisation), removal or reduction of trade barriers (commercial globalisation), and organising production systems (productive globalisation). Technology integration falls into the third stage, encompassing technology strategy, assimilation, training and development, operations and maintenance. At the same time, technology may require both adaptation to suit the operating context and development through incremental enhancements, innovations and evolutionary replication. Integration is achieved when control of technology permits radical innovations for new products (Kamur and Siddharthan, 1994; Niosi and Godin, 1999). In analysing the role of innovation in the application of technology, Buys (2002) presents an 'entrepreneurship paradigm' consisting of three types: forward integration (innovative capability development through scientific discovery), concurrent development (established industries investing in R&D to develop new and improve existing products), and backward integration (progression from sales of imported products by local companies through local manufacturing to development of new products). Buys contends that innovation in developing countries typically falls into the backward integration category, suggesting that the application of technology is not significantly developed.

Vieira and Zawislak (2002) expand on Hill's 'qualifying factors' and 'order gainers' in the context of technology integration. The first category (operations) comprises quality, integration, logistics and workforce skills; the second (competence and results) includes capacities, partnerships, development of new high quality products, and waste reduction. Alcorta (1999) suggests that firms in developing countries are primarily concerned with quality. Thereafter follow cost reduction, flexible production for a range of products, reduction of response times, and increased productivity. These require the ability to operate sophisticated technology with less skilled labour (Sambasiva Rao and Deshmukh, 1994).

Narayanan (1998) introduces a design framework for technology integration comprising a technological paradigm (to determine the level of technology adoption) and a series of technological trajectories (problem-solving for technology diffusion, and establishing manufacturing systems and procedures). Narayanan (1998) ascribes divergent outcomes in different firms using a common technology to different processes of technology acquisition (the technology paradigm) and differing technological trajectories of firms in the same sector. In order to remain competitive, firms change the technological paradigm (such as new layouts, skills and systems), by shifting from one technology to another, and by adopting a variety of trajectories. In addition to the 'technical' side, technology integration requires a review of organisational architecture and the structure of managerial control, decision processes and information systems. Fleury (1999) refers to these in terms of the interdependence between the spatial distribution of activities and resources (configuration), and functioning of productive facilities (co-ordination).

Deregulation has resulted in technological paradigm shifts that enable firms "to operate on a different technology frontier through which they can produce new and differentiated products" (Narayanan, 1998: 220). This is necessary as imported technology and local R&D alone do not result in successful shifts in technological trajectories. Narayanan suggests that unless trajectories developed under one set of technological conditions undergo appropriate modification, a change in the paradigm can remove all trajectory advantages. External technology partners are able to modify and assist in technology integration. Even with similar technology, trajectories (problem-solving methods) will vary. D'Costa (1995) gives examples of an Indian importer of Japanese technology that subsequently introduced Japanese management processes and production systems, whereas a user of similar European technology adopted European practices.

Kharbanda and Jain (1997: 440) refer to the need for a "well developed R&D infrastructure (and) the correct mix of foreign and indigenous technology". The countries discussed in the next section have embarked on this process. In India, for example, there are over 3000 scientific institutions and 1400 in-house R&D units in the industrial sector. The Indian government has established a 'Programme aimed at technological reliance' to support technology absorption in industry, and to build indigenous capabilities for development and commercialisation (Sikka, 1996). On a smaller scale South Africa has created a National Research and Technology Audit and a national foresight project. Alcorta (1999) gives examples where extensive use is made in Brazil by specialised research institutes and universities.

Technology integration in Brazil, India and South Africa

This section considers technology integration in Brazil, India and South Africa. These countries have different economic and political systems, but technology is an important component in their economic liberalisation. While their performance lags behind many Asian countries, they provide useful indicators for technology integration in South America, parts of Asia, and Africa.

Brazil: *Fleury (1999) has identified three stages of technology implementation in Brazil, each impacting on technology integration. In the installation phase (1950-1970) parent companies introduced technology, and integration took place through centrally determined reconfiguration and co-ordination. The second phase (1970-1990) was characterised by autonomous subsidiaries taking more configuration and co-ordination decisions. Transfer of technology and knowledge to subsidiaries was reduced, leading to a considerable degree of autonomy, but static technology.*

A subsidiary at the third stage becomes "a centre of competencies" (Fleury, 1999: 559), and so decides on configuration and co-ordination matters in an environment of increasing privatisation, industrial restructuring, and intensified productive globalisation. Despite the reintegration of subsidiaries as part of the global strategies of parent corporations, technology integration becomes increasingly important as subsidiaries remain responsible for the supply chain and production optimisation at regional level.

Although foreign firms in Brazil have greater access to capital, technological and managerial resources, they have not necessarily introduced the latest technology (Prochno and Corrêa, 1995). Factories built 20-40 years ago are 'locked-in' to old technology, and act as technology followers, even though some upgrading has taken place. Alcorta (1999: 168) points to the paradox that "while in most cases local supplier firms were being asked to automate by multinational corporation clients, foreign-owned firms were not".

India: *The Indian industrial environment has been characterised by regulation and protection (Nagabhushana and Shah, 1999). Deregulation policies were intended to introduce competition through technological upgrading in heavily protected, oligopolistic industries, characterised by restrictions on entry, diversification, capacity expansion, and imports (Narayanan, 1998). Local firms had little incentive to upgrade technology as profit margins and growth rates were high. Reforms after 1985 enabled Indian firms to expand their product range, introduce new technologies, and increase their capacities without obtaining prior official sanction (Pandit and Siddharthan, 1998). Technical collaboration between Indian manufacturers and European and Japanese automotive firms led to substantial upgrading of the local technology. By 1985, firms in the automotive industry had* *introduced conveyor belt assembly, some IT applications, and varying degrees of automation and robotics. Large inventories were lowered through flexible production, and new materials reduced overall costs. The changes constituted a paradigm shift in the industry with new layouts, skills and systems which existing firms adopted to remain competitive.*

Indian firms, like those in other developing countries have pursued a policy of cost reduction. Nagabhushana and Shah (1999) attribute this to movement up the development ladder, where cost is a qualifier criterion, while quality and delivery become order winning criteria. In a study of 95 Indian companies, Nagabhushana and Shah (1999) found that the most important manufacturing objectives related to cost and quality, followed by delivery and flexibility. Their study also revealed that automation was last in a list of 50 options.

South Africa: *Deregulation commenced in South Africa during the apartheid era, but sanctions constrained technology inflows and hindered the establishment of networks and supply chains. After 1994 the African National Congress government declared a policy of deregulation, followed in 1999 by a programme of privatisation in which several large public corporations were to be privatised or deregulated. South African businesses have always had to contend with government intervention. Technology policy was influenced when the apartheid government spent large amounts on capital infrastructure and subsidised private capital intensive projects. Also, restrictions on the use of blacks in the workforce aggravated shortages of skilled labour.*

South Africa's economy has been less regulated than, say, that of India. The government advocates a free-market policy on investment, wages and employment, claiming that "much modern production no longer lends itself to labour-intensive methods. Trying to force the economy in that direction would not create jobs" (Cling, 2001). The government therefore encourages an upgrading of the technological base of the country, but this is proving difficult as the workforce is generally poorly educated and because South Africa does not have the advantage of a low wage country. This is illustrated by considering the cost of producing one metre of fabric (in US cents): South Africa 86c, Brazil 42c and India 24c (Cling, 2001).

Empirical research from South Africa

The paper now turns to an examination of the perceptions of 200 South African managers who were attending business school executive programmes at the University of Cape Town in 2000 and 2001. The 30 managers attending the first in a series of programmes were asked to list the issues that they believed were important in managing technology. After clarifying what the managers had wished to convey in the initial listing, the authors eliminated overlapping issues, resulting in a list of 38 items. The managers in the first and subsequent groups were asked to score how important these items were in technology management, and then to what extent they could control them. The scoring was on a Likert scale of 1 to 5 for the following criteria:

How important this item is now, in so far as it affects your working environment

How much control can be exercised over this item now

How important this item will be in three years time

How much control can be exercised over this item in three years time

Factor analysis was used to group the items into a number of factors that would indicate the most significant components in technology integration. Details of the factors analysis are not included here, but Table 1 (see Annex) shows the 7 factors, and items in each category.

The purpose of this study was to obtain the opinions of, and insight into the perceptions of a strategically important sample of managers. In order to clarify and explain emerging results follow-up interviews, structured around the factors, were held with 40 managers.

The importance-control grid

The research follows the methodology of Naudé et al (1990) in studying the relationship between the importance of factors in a manager's operational environment, and the extent to which a manager can control them. Managers' tasks demand attention to important issues, but Naudé et al (1990) show that, particularly in transitional environments, managers frequently find themselves without sufficient control. By plotting the scores on a grid, the following distinct areas may be identified:

- *core issues*: the most important and over which most control can be exercised; these issues require the greatest management time, effort and planning
- *complex issues*: important but over which limited control can be exercised
- *simple issues*: of lesser importance and which are easily controlled by management
- *peripheral issues*: of limited importance over which little control can be exercised.

The grid provides a method for identifying problems and can be extended to suggest action to improve technology integration. The terms "core", "complex", "simple" and "peripheral" provide easy reference to the quadrants, but do not fully describe all possible combinations of complexity, importance, frustration and control. The form of the importance-control grid is shown in Figure 1, on which the current and future factor scores (but not the individual items) have also been plotted.

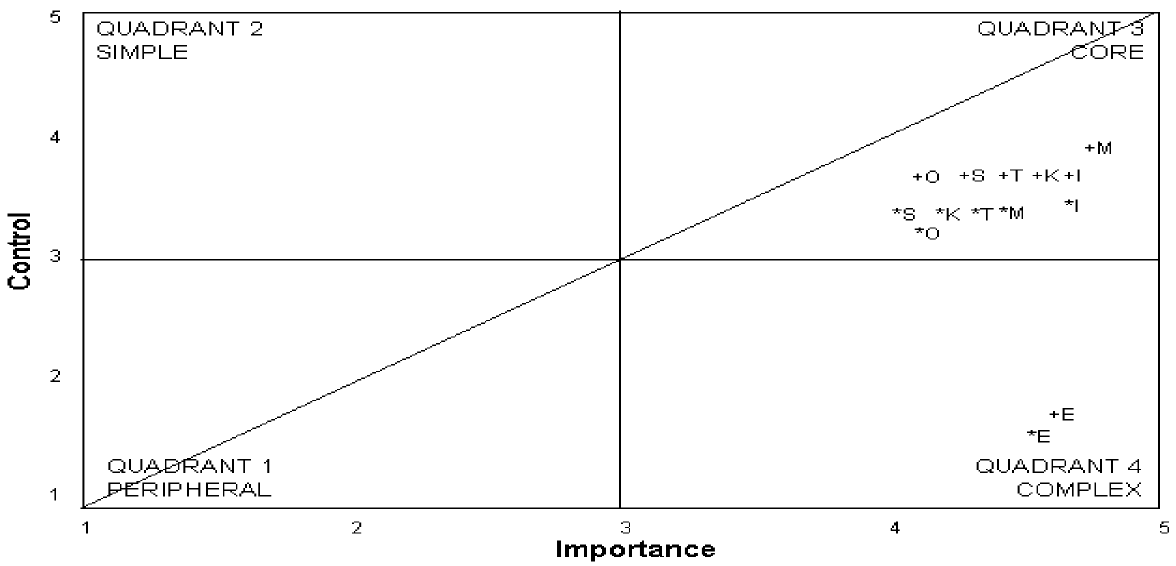

Figure 1: The importance-control grid - current and future scores

Key to abbreviations in Figure 1

T	Technology	S	Strategy	M	Maintenance
E	Economic/political	O	Operational management	I	Integration of technology
K	Knowledge				
1 =	not important/no control	*	present perceptions		
5 =	most important/much control	+	future perceptions		

The importance-control grid depicts the degree of alignment between importance and control: the greater the distance of a factor from the diagonal, the larger the degree of imbalance. This is likely to lead to frustration or inappropriate managerial intervention. The frustrating extremes occur in quadrants 2 and 4. Disproportionate effort on "simple issues" (quadrant 2) represents poor utilisation of managerial resources. The deemed importance of "complex issues" (quadrant 4) cannot be matched by an ability to control, since "complex issues defy understanding and manipulation, and can be expected to frustrate those dealing with them" (Naudé et al, 1990: 524).

Discussion of South African findings

This discussion concentrates on individual items (from Table 1) that reflect greater degrees of imbalance, and significant differences between present and future scores. The literature shows that technology integration contains many interacting variables, concurring with the views of managers that one cannot discuss technology integration in isolation of other factors.

Technology items lie in the core quadrant with the exception of the item "future technology complexity". Complexity importance is scored the highest, but managers envisage even less control over the complexity of imported technology in the future, particularly with the low operations and maintenance skills available. The scores support the contention in the literature that one of the main reasons for introducing technology is to achieve better quality and increased output. Managers emphasised the importance of retaining good relationships with suppliers in order to assimilate new technology and transferring competences.

Economic and political issues are in some respects unique to South Africa. All items lie in the complex quadrant indicating that managers consider these to be important but they are unable to control them. Crime and Aids are the most significant items, and will become even more important in the future. The low control scores illustrate managers' frustration that they are powerless to do much about crime, poor education, low levels of infrastructural development and government regulations. Some managers commented that by the standards of other developing countries, South Africa's infrastructure is good, but the general economic outlook is not encouraging, particularly because of Aids (up to 250 000 South Africans die each year from Aids), crime that deters foreign investors and leads to increasing emigration by skilled people, and political instability in surrounding countries.

Knowledge and understanding new technology are essential for the introduction of new technology, as testified by high importance scores. Managers see scope for enhancing control over this through training and development, but this is an arduous process with a poorly educated workforce. Some managers believed that as a developing country South Africa has more pressing priorities than developing a knowledge-based economy, so the notion of the learning organisation through intangible knowledge diffusion is likely to receive limited attention.

Strategy items, currently scored the lowest in importance and all lie in the core quadrant, apart from globalisation. The new business climate is important for technology strategy, but managers cannot control this. The drive for new technology is in response to local demand and global challenges. These will increase in the future, as managers envisage greater control over strategic items and technology-driven strategy delivers competitive advantage. The use of technology in shifting from a product to a process base is recognised as an enticing development, but managers see limited scope for this unless an integrated system encompassing modified product designs and corresponding production equipment can be acquired. Several managers indicated that the market in South Africa and other African countries was too small to justify new technology. If South African firms did not improve their competitiveness then foreign suppliers would take over the market. Quality standards, increased output and flexibility could only be achieved by introducing new technology.

Operational management issues with their relatively low control scores will frustrate managers. The most important issues are lack of labour commitment and low productivity, and the costs of training and developing a poorly educated workforce. Managers accept that the state cannot provide all requisite skills, despite a new training levy, so businesses must take the initiative to develop their own staff. Whites perceive empowerment as a political issue, whereas blacks see it as a socially responsible part of the normalisation of the industrial environment.

Maintenance importance scores are among the highest, and show how this factor will become even more significant in the future. Managers will control this through a variety of maintenance interventions. The emphasis is on proactive maintenance that moves beyond repair and replacement to delivering functionality in accordance with desired performance standards.

Integration of technology receives the highest current importance scores as benefits will only accrue if technology is comprehensively integrated. Machine and systems integration was highlighted, as was the recurring importance of training local technicians and operators. Shortages of skilled personnel will remain a problem for technology integration, over which managers do not envisage much control.

Discussion of empirical findings in a broader context and conclusion

While some of the results from the South African study are relevant only to that country, others support the findings in the literature and apply generally to developing countries. South Africa and Brazil are ahead of India in terms of Fleury's stages of globalisation: financial markets are generally deregulated (although some exchange controls remain in South Africa) and many trade barriers have been removed. Productive globalisation is open to market forces. Political and economic events remain long-term threats in regions of potential instability.

The empirical study supports both the interdependence of configuration and co-ordination (Fleury, 1999), and the technological paradigm and trajectory concept (Narayanan, 1998) for technology integration. Configuration issues relating to the distribution of activities and resources depend on technology strategy but may be restrained by productive facilities (co-ordination). Developing countries try to compete globally with inferior or older equipment, which they are not able to operate and maintain as well as their developed competitors. Interviews with South African managers support the contention that financial constraints limit the extent of technology-led strategies.

The technology paradigm influences technology assimilation and adaptation in collaboration with technology suppliers. Strategic objectives create the basis for technology policy within a country's economic and political environment. The rationale for new technology is improved quality and cost reduction, while technology trajectories provide the mechanism for integration. Technology policy in developing countries generally falls into the backward integration category (Buys, 2002) in that technology is developed elsewhere and adapted in developing countries as a manufacturing process. The operational management and maintenance policies applicable to technology depend on understanding the technology, ensuring appropriate levels of worker expertise, and providing an integrated approach to change management, communications and systems.

Several examples demonstrate successful integration of technology and operations. In the Brazilian and South African automotive sectors, manufacturing plants have been expanded significantly and cars are exported worldwide (India does not currently export motor cars). Software development in India has proved a robust and rapidly expanding sector. Yet, De (2002) attributes India's lack of technological progress to a number of factors: misalignment of technology policies and national strategies, poor quality and weak technology infrastructure leading to a lack of international competitiveness and poor export performance. He further criticises government policies for not being conducive to foreign direct investment. The empirical results concur that government policies play a significant role in technology investment decisions, as well as day-to-day operational issues.

In Brazil, Passos and Sbragia (2002) have found that technical skills, long-term contracts, information transfer, and technical support for quality control enhance knowledge transfer, as part of the integration process. They have also found that multinational companies no longer invest the entire range of their technologies in single countries, because of the ease with which technology can be spread globally or components acquired through efficient supply chain management. Several South African managers also suggested that technology suppliers did not always provide the latest technology, and that a competitive threat for developing countries was the extent to which multinational companies used global sourcing policies for components and products.

The importance-control grid is useful as it shows the importance of both configuration and co-ordination, while highlighting the degree to which trajectory control is possible. Managers have some control over configuration, despite resource and skills constraints, but their influence over co-ordination is limited in several key areas. The research shows the importance of strategic technology decisions, and recognition of the relationship between technology paradigms and the trajectories.

Successful high-tech applications are found in the three countries selected for this study, demonstrating that under the right circumstances technology and operations integration can be achieved. The main challenges are providing the appropriate macro environment and the internal conditions that will support new technology. Moves towards deregulation and privatisation reduce the influence of governments in technology decisions and applications, yet private corporations look to the state to ensure an investor-friendly environment. The research shows that this interrelationship between governments and private firms will continue to be an essential feature of technology and operations integration.

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Annex - Table 1 Factors influencing the management of technology

	Factor loading		**Importance now**	**Control now**	**Importance 3 years**	**Control 3 years**
T		**TECHNOLOGY**	**4.4**	**3.4**	**4.5**	**3.7**
T1	0.891	Assimilation of new technology	4.3	3.1	4.5	3.5
T2	0.844	New technology to meet exact needs of customer	4.4	4.0	4.5	4.6
T3	0.708	Appropriate technology base from partnership	4.3	3.8	4.4	4.0
T4	0.663	Transfer of core technology from owner to acquirer	4.0	3.0	4.3	3.5
T5	0.662	Complexity of technology	4.6	3.2	4.8	2.4
T6	0.619	Better quality through technology	4.6	3.4	4.6	3.9
T7	0.615	Improved output through new technology	4.4	3.6	4.6	4.1
E		**ECONOMIC/POLITICAL**	**4.6**	**1.5**	**4.7**	**1.6**
E1	0.923	Crime levels in South Africa	4.8	1.4	5.0	1.4
E2	0.858	Unions, affirmative action and employment equity	4.7	2.0	4.4	2.4
E3	0.791	Low educational levels of labour	4.8	1.7	4.9	1.6
E4	0.745	Aids	4.9	1.3	5.0	1.4
E5	0.696	Level of economic development and infrastructure	4.2	1.4	4.5	1.3
E6	0.608	Government regulations and bureaucracy	4.0	1.2	4.4	1.3
K		**KNOWLEDGE**	**4.3**	**3.4**	**4.6**	**3.7**
K1	0.926	Understanding of new technology	4.4	3.5	4.8	3.9
K2	0.865	Understanding hardware and software	4.3	3.8	4.5	4.0
K3	0.828	Codification and documentation of knowledge	4.5	3.6	4.7	4.0
K4	0.776	Diffusion of intangible knowledge	4.1	2.5	4.3	2.8
S		**STRATEGY**	**4.0**	**3.4**	**4.4**	**3.7**
S1	0.839	Technology implemented because of market demand	4.3	3.9	4.6	4.2
S2	0.802	Technology as strategic for competitive advantage	4.4	4.2	4.7	4.5
S3	0.787	Technology agreements (licensing, JV, partnership)	3.9	3.7	4.3	4.0
S4	0.746	New relationships with stakeholders	3.7	3.1	4.4	3.4
S5	0.744	Technology for shift from product to process base	3.9	3.2	4.3	3.8
S6	0.656	New business climate (global markets)	4.0	2.0	4.4	1.8
S7	0.558	Technology permits revisit of vertical integration	3.9	3.7	4.4	4.0
O		**OPERATIONAL MANAGEMENT**	**4.1**	**3.2**	**4.1**	**3.6**
O1	0.884	Lack of labour commitment and low productivity	4.6	2.0	4.8	3.0
O2	0.858	Empowerment	3.7	3.8	3.9	4.2
O3	0.784	Cost of training and developing local workforce	4.5	3.0	4.5	3.9
O4	0.773	Promoters/champions essential for new technology	3.8	4.3	4.0	4.4
O5	0.587	Short term operational returns from technology	4.0	3.0	3.3	2.7
M		**MAINTENANCE**	**4.5**	**3.4**	**4.7**	**3.9**
M1	0.799	Availability and reliability of equipment	4.7	3.6	4.8	4.2
M2	0.743	Safety assurance through maintenance	4.6	3.2	4.8	3.5
M3	0.685	Appropriate maintenance policies	4.6	3.4	4.8	3.8
M4	0.623	Understanding impact of failure on overall process	4.2	3.4	4.6	3.9
M5	0.608	Failure data	4.3	3.6	4.5	4.0
I		**INTEGRATION OF TECHNOLOGY**	**4.6**	**3.5**	**4.6**	**3.7**
I1	0.919	Integrating new technology with existing systems	4.6	4.0	4.7	3.9
I2	0.887	Development of communications and IT systems	4.5	4.1	4.1	4.2
I3	0.825	Training by suppliers in the use of new technology	4.3	4.1	4.5	4.5
I4	0.747	Shortage of skilled personnel	4.8	1.7	5.0	2.0