Defence Science Journal, Vol 46, No 3, July 1996, pp 181-193

Technology Management in our Liberalised Environment

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ABSTRACT

The article reviews the present state of technology management in our liberalised environment. For our industries, technology management is mainly technology import and for our scientists it is management of R&D. The changes introduced in technology management by the intense competitive environment are discussed and the effects of the broadened scope for technology management for sustained competitiveness are brought out. Technology fusion and core competence as part of the strategic framework follow as a response to the environment. The Indian scenario is now discussed in the light of these developments. The paper concludes that all parties involved in technology management namely, government, industries and the scientists/technologists have to recognise these changes and act in a concerted manner for the nation to gain and sustain the competitive edge.

1. INTRODUCTION

There is no gainsaying of the fact that increased profits and enhanced exports have created in Indian industry, a sense of optimism and greater confidence to overcome the problems envisaged earlier due to liberalisation of trade and industrial policy by the Government. The improved performance can be attributed mostly to the availability of inexpensive capital and in a smaller measure to improved labour productivity. It is clear from the various pronouncements made by the heads of industries that industry in the private sector is and will be spending resources on technology imports for improving productivity. It is also a matter of record that repetitive imports are on the rise. These re-inforce the belief that industry has interpreted the catch-up process through technology management as exercising the 'buy' option without a commitment to strengthen a 'make' option for the future through in-house or indigenous R&D. This has evoked a response from the Prime Minister of India who in his address to the 82nd session of the Indian Science Congress has urged the industry to look beyond factors like capital and labour and confirm the importance of technology development as a determinant of economic growth. The tilt of our industries to technology import instead of technology management is in complete contrast to the attitude of industries in developed countries where technology management is a crucial element of competitive advantage. The focus of management in these countries is on the understanding and resolving of the complexities added to decision making due to high rate of technological change, technology deployment, ability of competitors and new comers to catch up with leaders in short time, strategic planning upstream, and restructuring of the organisation including the R&D to make it more responsive to market forces.

2. PREREQUISITES FOR TECHNOLOGY CATCH-UP

According to most economists, the key elements in the process of catch-up in economic growth are: investment in physical capital, availability of educated and trained manpower and general management capabilities[1]. This is based on the simplistic assumption that the process of technology import gets reduced to technology transfer which is costless. It is unrealistic because technology is more than a set of discrete techniques each of which can be completely codified and contained in a 'book of blueprints', material inputs

Received 11 September 1995, revised 07 February 1996

and the physical means for accomplishment. Further, many case studies of technology imports from developed to developing economies have revealed that the tacit component of knowledge about technology can only be acquired through investment in learning which is grounded in purposeful analysis of information gained through practical experience, and is vested in the R&D institutional infrastructure set up for the creation and utilisation of technology. Such investments in learning lead to assimilation, duplicating understanding that exist without adding to the stock of existing knowledge, to invention and innovation, creating new elements of reproducible technology that yield equal or higher productivity under local conditions[2].

Technological investment has two components, namely, the degree of external participation and the internal technological capability acquired through previous investment in technology. Management of technological advancement, therefore, involves choice of changes to be made and the investments to be undertaken for bridging the technology gap. The imported technology has to be checked for circumstantial differences and for sensitivity to circumstantial differences. Circumstantial differences cover physical economic and social differences such as material input characteristics, climatic conditions, income levels, consumer preferences, factor costs, etc., between developed and developing nations. Important proof of circumstantial differences can be evidenced from engineering activities that occur when new production facilities are being established. For example, in the case of natural resource-intensive products such as steel and cement, in several instances the imported technology had to be suitably adapted to accept the locale-specific peculiarities in the raw material characteristics. In general, if the circumstantial differences between the countries are small and if the sensitivity gradient is small, little adaptation would be necessary and can be carried out by production engineers without formalised R&D. However, as the gap between a developing and a developed country is greater, major, intense adaptation would be needed because the knowledge that underlies the technique is crucial to bring forth offsprings suited to local needs[3]. This intense adaptation requires formalised R&D capabilities.

3. TECHNOLOGY CATCH-UP

In many respects, the technology catch-up process followed by us is that expected of a developing nation with strong educational/training base, low levels of productivity and export trade orientation. At the level of the firm, productivity growth is being accelerated with the import of technology from the more advanced economies. Analysis of the technology catch-up process by developing countries reveals that products or processes of technology imports are mostly those which have reached the maturity phase of the life cycle. In such cases only minor adaptation is adequate since the process of product stabilisation and production optimisation has already been accomplished. Again, from the study of the NIEs (newly industrialised economies) it can be reasonably concluded that this is only the initial stage of the catch-up process from which it would be important for the country to move out once the wages rise due to increased expectations. Then, Indian industries can no longer depend on inexpensive labour for assembly-type mass production industries[4]. Additionally, there will be increasing competition from other low-wage countries who will be following a similar route for economic expansion. Finally, since the competitiveness of the labour-intensive assembly manufacturing operations is also based on the availability of production equipment and upstream components from the collaborators, the latter may use their oligopolistic status over the input of components to slow down and limit the expansion of Indian companies to thwart serious competition in their markets.

After a few year, India too will be forced to follow suit but before we do so, industry has to strengthen its in-house R&D to be capable of undertaking intense adaptation as well as incremental innovations to improve the scope for grafting an outside transplant and to keep the costs down. At the national level, the innovation strategy for sustaining competitiveness will have to be a mix of in-house R&D of the industry, indigenous R&D at academic, government and cooperative R&D institutions and technology imports. A number of factors such as the nature of R&D, the degree of risk aversion, availability of foreign technology, mode of technology transfer, the institutional framework for adaptation and the extent of support given by the government to high-risk projects will influence the decisions. A thorough understanding of the mechanism by which technology advances, the nature of technology and product life cycles, the nature of R&D activities and strategies for creation/sustenance of competitive advantage are necessary for managers of technology to establish an appropriate balance.

4. PATTERN OF TECHNOLOGY ADVANCEMENT

From available empirical evidence, it is clear that the basic trends in technology progression are determined by periodic appearance of innovations as a result of rational human decisions based on costs and benefits. The innovations signify a variety of new departures in competition with prevailing practices. Since economists have accepted technical change as a fundamental driving force of productivity growth, the study of the occurrence of and the events leading to innovation assume importance. Schumpeter was the first economist to suggest that technological innovations manifest as uneven discontinuous phenomena, which result in a series of jumps and in wholesale shift in technology and in the knowledge base. He also stated that innovations tend to cluster because first a few and then most firms follow in the wake of the successful innovation. The organisation culture that subsequently developed in the West emphasised technology breakthroughs, the bold idea and the brilliant concept to have an unassailable competitive advantage. All alternate manifestation of innovations emphasised the continuous nature of innovations and stressed that systematic continuing improvements alone can overcome the teething problems in the case of radical new products and processes. These improvements would continue throughout the life of the product so that a combination of learning by doing and learning by using can yield strong productivity gains for a considerable period. This gained prominence in the West only after the Japanese turned it into a powerful tool to create and sustain the competitive edge in such fields as consumer electronics, semiconductors, robotics, fibre optic communication and automobiles[5-8].

In general, radical innovations are large and discrete changes in technology in which new ideas without precedent emerge more or less *ab nihilo*, occasionally. They are followed by incremental innovations which are small cumulative gains that improve, adapt and streamline the processes and products to minimise costs, enhance performance, increase reliability and reduce the input requirements. The radical and the incremental innovations are complementary. A satisfactory theory of innovations therefore must include the radical innovations, and the innumerable incremental improvements that follow. Radical innovations involve structural changes in economy and ultimately lead to entirely new applications and to new branches of industry. These are the main sources of dynamic development; by definition they need quite new skills and in many cases a different management organisation and production equipments. Incremental innovations contribute to the economic success of the radical innovation and the range of improvements that can be carried out are substantial. However, these would ultimately be limited by the constraints of that particular technology.

Technology advancement has been observed to follow preferential paths known as technology trajectories. In a limited sense, the edifice of technology in an industrialised society can be compared to a jigsaw puzzle with the pieces corresponding to established technologies fitting in an intricate and precise manner. This edifice is ever changing and expanding. The changes in the edifice of technology are brought about firstly, to counter the threat of new technology that is entering and secondly to meet the felt needs of society. The expansion of the technology edifice comes about from those new technologies which find a range of new applications which could not be had with earlier technologies and thus provide the necessary trigger for expansion of societal needs. Antibiotics and integrated circuits are typical examples of such new technologies. New technologies however, do not replace the older technologies in all their spheres of applications. For example, in the case of integrated circuits, they could replace vacuum tubes and discrete semiconductor devices in all but medium and high power applications. Thus, new technologies enter into the corpus of existing technology base only if they can demonstrate attributes that are superior to established technologies they are meant to replace and find applications at an early stage. The success rate of a new technology is not likely to be high since it cannot function in isolation to in the needs of the society, the existing infrastructure and the prevalent technologies[9-11].

Once the new technology has been demonstrated to perform successfully, thousands of 'helpers' seeking additional uses come into existence. The aggregate impact of such additional applications cannot be normally estimated before hand. Consequently, managers of technology are confronted with a threatening paradox. They may be right in dismissing the likely impact of new technology in a large majority of cases but if they miss the rare event of a new technology being eminently successful, they are considered as failures. Achieving a sound balance between continued concentration on established technologies and diverting adequate effort to introduce new technology requires technology managers to understand the technology life cycle (TLC), which is also the corner-stone for understanding the market behaviour of the products.

5. TECHNOLOGY LIFE CYCLE

Broadly speaking, technology life cycle undergoes distinct stages of growth and stabilisation before it is phased out by a new technology. These are, the Embryonic, the Expansion, the Maturity and the Ageing stages[12]. In the Embryonic stage the process is one of technology pioneering by which the firms create and introduce new technologies to the market well ahead of others. It is closely related to radical shifts in a technology spurred by major scientific advances.

Pioneering can strengthen a firm's competitive position by increasing its market share, enhance its reputation and name-recognition and improve its financial position. It is also a double edged sword because many pioneers have failed to achieve market leadership. For example Xerox, a, pioneer in graphic interface software, failed to follow it through in market leadership, leaving it to Microsoft to create and commercialise the software. The objective of all competitors in the Embryonic phase is to keep the situation in a state of flux by offering a large number of products and a great variety of services or applications. For an enterprise to emerge as a leader at the end of the Embryonic phase, it has to invest heavily from a very early stage in establishing its technology and later to achieve economies of scale. This would enable the firm to redefine the boundaries of industry and rules of competition for the reward of market leadership. For instance, in the 1970s while many firms recognised the eventual convergence of computing and telecommunication technologies, only NEC of Japan committed its resources to make this convergence the central theme of its strategic decisions. Similarly, the examples of Microsoft, DEC and Apple show us that by making technology as the focal point in their strategy, they created a competitive advantage by offering unique products, lowering costs or both. These companies understood the role of technology as the mainspring of differentiation in the market place and used their respective technological expertise to offer a different bundle of products, services and price ranges covering a wide range of customers[13].

Eventually, customer preference settles on one or a few products out of the many and the reward of market dominance goes to those firms whose products have been preferred. One way for any firm to achieve dominance is to promote its product as the industry standard in reliability and in performance. In general, the dominant design can be recognised from the following characteristics. Firstly, the technology and the product overcome the present constraints of the existing technology without imposing stringent new constraints. Secondly, the design has flexibility to accommodate and possibly enhance the value of potential innovations in any of its components or processes. Further, the product and the technology find applications in new areas. Finally, the product makes use of the existing infrastructure rather than replacing it totally right at the beginning. The emergence of the dominant design triggers the beginning of the Expansion phase. In this phase, the set of successful competitors are likely to become an oligopoly and the process of 'survival of the fittest' stabilises the industry. Competition begins to shift the emphasis to price and mostly improvements and refinements of the dominant products and their clones take place to meet the growing market needs. The objective in the Expansion Phase is to improve the productivity and make product differentiation difficult so that the innovator with first-to-market advantage can produce more efficiently and consistently. The stimulus for innovation arises out of the new opportunities created by the expanding scope of application. The firm for its survival must have atleast one product which is stable enough to have significant production volume. The effectiveness of the strategy by any of the players in this game is thus governed by the breadth of their product line, the strength of the distributor network and the quality of after-sales service. As the Expansion Phase nears its end, performance criteria of each product is stabilised. The production processes become further stabilised and no changes in production processes are likely to be undertaken unless it is mainly for achieving greater vertical integration. The market stabilises by the time Maturity Phase is reached and pressure mounts to reduce costs and improve quality further. More and more, the attention of the managers and the technical personnel will shift from improvements in capability to improvements in processes for achieving lower cost. The effort to achieve additional technical advances becomes more difficult and the improvements are likely to be marginal and less frequent. At this stage of the technology cycle, both product and process features are well articulated and analysed. Therefore, manufacturing effectiveness and production engineering assume importance. By the time the maturity phase is reached halfway, the firms will be ready for technology transfer to expand their market abroad without too much capital investment. As the Maturity Phase draws to an end, process technology would have become more sophisticated and specialised to cater for high volumes with lower per unit profit margins. Competitive success calls for effective management of assets and managers become more financially oriented. The excitement of working in such a technology is reduced with the result, younger and, brilliant minds turn away from this type of work.

The beginning of the Ageing Phase of technology is marked by a progressive increase in costs for additional improvements, intense competition, customer reluctance to pay for features and pressures to reduce prices. Since every technology has a theoretical upper limit of performance imposed by nature, as time passes the probability that a new technology which has been already invented, will overtake the earlier technology, increases rapidly and becomes certainty.

The technology life cycle described above follows the S-pattern with time. While this is the classical pattern, in specific cases where the application of an established technology beyond the maturation stage has found new areas, the life cycle returns to a lower point in the S-pattern and its life is prolonged.

Therefore if managers can correctly estimate the onset of maturation and subsequent passing to Ageing Phase, they would be at an enormous advantage compared to their competitors. However, in general, it is difficult to know in advance the point in time when the slope of improvement reaches its maximum on the S-curve. Whenever a new technology that is lower in the S-curve begins replacing an existing technology which is high up in the S-curve, a technology discontinuity occurs. So long as the technology life cycle covered long time periods the effects of discontinuity were not felt. With high technology, however, the discontinuity effects are likely to be significant due to shorter period. Technology discontinuity affects the employees, the production processes and the organisations engaged in the business. Clearly, the crucial task is not only to decide on the likelihood but also to determine the timing of the emergence of a candidate new technology as a genuine threat.

Finally, it has to be noted that even though all established technologies are ultimately replaced by new technologies, the success rate of a new technology is limited due to the complexity of modern society[15].

6. CONSUMER PRODUCT DEVELOPMENT

A technology in the Embryonic and Expansion Phases creates many products each of which has a product life cycle. In the case of the consumer products, the product life cycle is governed mainly by three basic parameters, namely, fashion, technology and the customer needs. Fashion is defined as change for the sake of change and when product changes are effected to cater to the needs of fashion, it involves addition of enhancements, relatively modest technical improvements, and resolving field-operating problems to gain advantage over competitors. In general, a typical product may undergo many improvements and modifications but it only serves the same purpose in a different way. Very often, the short life cycle time referred to in management studies is likely to generate wrong impressions of rapidly changing competitive markets with technology as the differentiator for the product whereas in reality, it involves relatively minor or incremental improvements. A clear distinction therefore has to be made between the product life cycle time with technology as the differentiator and the product, life cycle time resulting in minor improvement[16]. The example of Sony's Walkman series illustrates this aspect very well. The same trend persists in other consumer products such as television receivers, telephone instruments, washing machines, refrigerator, etc. As most of these are labour intensive and since the technology changes are cosmetic, they are fit candidates for developing countries to consider first in their drive for expanding their economy.

7. INDUSTRIAL PRODUCT DEVELOPMENT

In the case of industrial and professional products, the users place substantially less value on fashion and hence the change stems from advances in technologies underpinning the product. Thus, in these cases technology is a critical factor affecting the market popularity of the product. To arrive at the state-of-the-art product, considerable work in relevant technology areas has to be carried more often without any specific product in mind. The appearance of innovations leading to the-state-of-the-art product are thus partly causal and partly serendipitous, because efforts to advance technology can be focused in directions that innovators believe to be feasible and potentially profitable. This type of R&D is more commonly known as Exploratory R&D and is defined as investigation of alternate technologies with the aim of finding out their natural limits. These investigations do not have any specific area of application or processes in mind. Market applications for future applications for the discoveries in Exploratory R&D may be found after the work is completed and in many cases it may end up in the form of defendable patents. Even if an application is found, the effort to develop it further for specific application will be limited in this phase of R&D activity. Exploratory R&D activities are best suited to the academic environment and hence can be funded at our advanced academic institutions. The measure of success is whether it can be further exploited to find an application in the market place. The decisions involve resolution of technology issues related to broad areas of application. Personal contacts and formal presentations by the Exploratory R&D to others including manufacturing personnel will be necessary to minimise the time delays and information gaps.

The later part of the activities for the state-of-the-art product will be directed towards utilising the technologies that have been found feasible for adaptation to perceived market needs. The R&D at this stage is termed Strategic R&D and is defined as investigation in science and technology areas worked upon in the Exploratory R&D phase and which are most likely to be helpful in reaching agreed upon goals of the nation or the firm. In this case the goal is defined first in terms of the broad parameters of a product or process and the R&D activities are then planned towards realising the goals. The Strategic R&D focuses on the most promising technologies and applies them to specific application areas of interest and for which broad specifications have been evolved with the participation of marketing and management. At this stage, the participation of Short-Term R&D and manufacturing will be in the form of providing useful and necessary inputs based on their assessment of the market and to steer the R&D to arrive at solutions that are implementable within the scope of the resources of the firm. It also helps marketing and manufacturing to plan their future activities by taking decisions on additional resources, adequate processes, raw materials or substitutes and so on. In addition, Short-Term R&D will carry out trade-off studies in design between various technologies, labour versus capital requirements, training of personnel etc. Depending on the complexity, one or limited numbers are assembled for and evaluated by knowledgeable customers for the attributes rather than for the benefits. The activities at the end of the Strategic R&D phase of product development also remarks the end of technology dominated phase and signifies the beginning of market driven philosophy of product development.

The remaining phases of product development more or less correspond to the later half of the Embryonic Phase of the technology life cycle. The R&D activities in this phase relate to Short-Term R&D which is defined as the process of exploitation of new techniques/technologies to design products that are practical, reliable and manufacturable. The focus now shifts to product design, prototype/pilot plant operations, and product evaluation/testing, that is, to all elements of activities required to demonstrate the capability of the product and the integrity of the design specification during manufacture.

Short-Term R&D activities related to the product are best carried out at the industry which is market oriented. The R&D emphasis at the end of the Expansion Phase shifts from product development to process R&D. With the emergence of the dominant design, industry would also have achieved the standardisation sought by the customers. The Maturity Phase and the Ageing Phase of the life cycle will now follow.

8. CURRENT TRENDS IN TECHNOLOGY MANAGEMENT

In the face of increased competition, due to shortened product life cycle and entry of more industrial enterprises/countries than ever before, there is a widespread acknowledgement that the present concepts and methodology of technology management need to be improved upon to gain sustainable competitive advantage. Technology as a competitive weapon gave rise to technology management which was translated in the two decades after nineteen fifties as management and control of R&D in the form of project budgets, time tables for completion and estimated returns on R&D investment, etc. During the decade of the nineteen eighties, the management control paradigm was further refined to evolve a strategic approach in which technology was considered as an essential element of strategy and was integrated into the strategic thinking and planning process of the enterprise. It was found that since this philosophy was adopted by a large percentage of firms in a very short period, its impact as a competitive advantage was diluted. It is now realised that a technologically driven sustainable competitive advantage depends not only on technology and its integration with strategy but also on the mode of acquisition and later of deployment. Analysis of companies with successful track record over a long period brings out that technology acquisition should be carried out preferably after analysis of inputs from different functional groups of the enterprise such as marketing, manufacturing, engineering, R&D etc. This adds to complexity to technology acquisition since each functional group is likely to formulate and apply its own criteria. The availability of variety of methods for technology acquisition and of several strategies for technology deployment add further complexity. In effect, the industrial enterprise will have to turn into a continuous learning organisation to sustain the competitive advantage[17].

The question of technology acquisition as part of the strategy for competitive advantage arises because of the fact that radical innovations which provide an unassailable advantage seldom occur. The Japanese have countered this uncertainty by technology fusion which is the process of integration of diverse established technologies into hybrid technologies to reap economic benefits similar to that of a radical innovation[18]. The proliferation of several new generic technologies over the last three decades, provides considerable opportunities to combine multiple technologies in a modular configuration so that the designers and planners have scope to take advantage of progressive improvements in the constituent technologies for commercialisation. Technology fusion is particularly suited for providing competitive advantage for products of consumer electronics as well as for industrial products. Since the search has to be carried out in core as well as peripheral technologies ahead of actual product realisation, the costs of search in technology fusion are likely to go up as more and more peripheral technologies are included for study and analysis. Further, as it is not possible even for a large industrial enterprise to create and maintain expertise in all the peripheral technological fields that may be of interest to sustain competitive advantage, technology acquisition appears to be a viable alternative. A combination of global alliances, technological consortia, contract R&D, joint research, joint ventures and licensing with those who have the required expertise in peripheral technologies would lead to the lowering of the R&D costs.

9. TECHNOLOGY FUSION

Technology fusion is considered to be a nonlinear process because incremental technical improvements from peripheral fields (with respect to an existing product) of technology are blended to create products that revolutionise markets and therefore create the same impact on economic growth as the radical innovation but without its structural shocks. In this case, the perceived new market is the driving force. The primary risk for the technology manager is the selection of the right technologies on which to base a product to fill an identified customer need from a wide range of possible alternatives. The R&D manager converts the vague needs and wants of the market based on basic customer values into specific R&D projects well ahead and resolves correctly the dilemma of what technologies to focus on and where to look for them. The challenge is in the application and packaging of existing technologies to match the characteristics of the market that is sought. The R&D activity is now market driven and has to deal with such questions as the suitability of the product features to the market, the superiority of the product over the existing hardware/software, the new functionality in the product and whether these will provide the required competitive edge, etc. Technology fusion results in convergence of technologies some of which were formerly peripheral to the commercial and research activities of the firm. It brings them to the centre stage and makes them as key elements of competitive advantage. Thus, the R&D manager also has to ensure that the group develops expertise in a broader array of technologies and scientific disciplines. However, it is not always possible to grow expertise in-house in an economically viable fashion and in time. Therefore, the strategic framework of the enterprise should incorporate technology acquisition and deployment. Traditionally, the objective of technology acquisition is to scan, shift and absorb technology applications relevant to the mission of the organisation.

One has to go beyond this and assimilate the technology acquired from outside sources. Success in technology assimilation will result in the transformation of the enterprise into a 'continuously learning organisation'. An example of technology fusion R&D is mechatronics, a term coined by Fanuc of Japan for new developments incorporating electronics in the field of machine tools.

10. CORE COMPETENCE AS STRATEGIC FRAMEWORK

The core competence view of the organisation is a new strategic frame work proposed by Prahalad and Hamel, linking technology to market and also for enhancing the innovation capacity of the organisation[19-22]. It is a methodology that is expected to provide more than adequate return on R&D investments by spreading the cost over several end-product lines, an end-product being defined as a revenue generating user/customer deliverable. It exploits the features of design modularity and of multiple technologies for end-products. It calls for a shift of the long term focus as well as of the short term emphasis from specific end-products to a set of products to reap the benefits of potential synergies between them. Of the many modules which configure an end-product there will be one or more in the form of component or a subassemblies which contribute significant customer value to the end-product. These are the core products and they are physical embodiment of one or more core competencies.

Core competence is defined as a base skill or a combination of base skills which should satisfy atleast three simple criteria, namely, (i) it should be a source of competitive advantage, (ii) it should transcend single product lines and cover a wide range of products, and (iii) it is hard for competitors to imitate.

For an R&D organisation, core competencies are those core attributes which enable it to integrate expertise from diverse disciplines, harmonise the know-how generated and acquired and organise the work to come up with end products and services that (i) are unanticipated by the competitors, (ii) invent and shape consumer demands, and (iii) enter new markets rapidly and successfully.

In short, core competence should enable the R&D institution to sustain competitive advantage. The core competence view of the organisation must be comprehensive and yet simple to communicate. The success of the core competency based enterprise depends on the communication, involvement and a deep commitment to working across functional and project boundaries. It involves many levels of people and provides opportunities to individuals with skills and expertise for blending their functional expertise with those of others in new and interesting ways. The core competency management overcomes the restricted view of end-products and focuses on the basic customer values that are perceived by the customer in the end-products. The customer values do not change as fast as an end-product and the expertise to exploit such customer values as low cost design, reliability, higher productivity, take longer time to acquire. Technology deployment within the organisation should therefore aim to enhance core competence and can manifest in the form of providing high value to customers, raise or change technology standards, offer a cluster of technologies instead of a few, provide interrelated family of products, etc.

The concepts of core competence, core products and their link to end products can best be illustrated by the examples cited by Hamel and Prahalad in their book. Some examples of core competencies are miniaturisation and video competencies for Sony, engines and power trains for Honda, network management for AT&T, fine optics miniaturisation and mechatronics for Canon, user friendliness for Apple and display systems for Casio. Laser printer 'engines' for Canon, compressors for Matsushita, and engines for Honda, are some examples of core products which have given to each of the organisations a dominant position in the global market. The example of Canon which has generated a wide variety of end-products such as copiers, laser printers, FAX, cameras and cam corders from the core products namely the laser 'engine' and the miniaturised motor provides a clue to the R&D methodology used in such organisations.

For example, the laser engine delivers a basic value of desktop printing to the laser printer. The core products are supported by the core competencies cited earlier. While each end product is managed by a separate group for commercial exploitation, all of them have the same underpinnings of shared core products and core competencies. After a core product was developed, Canon was able to pursue allied businesses, namely, fax and personal copiers. As a result, Canon has profited from the gains of economies of scale and an ability to turn out new products faster than competition. Further, without the embodiment of the three core competencies in the laser printer engine, continuous improvements would have been difficult and the company would not have been able to sustain long term competitive advantage.

There are several aspects of core competence that have to be understood. Firstly, the demand for core competencies is seldom uniform and varies widely with core product combinations. Secondly, the range of technical disciplines required for core competencies is frequently extensive. Thirdly, the scope of activity regarding core competence is often broad, ranging from research, design, system application and operating expertise. Fourthly, core competencies of the technical type can rarely be built instantaneously. Therefore the number of core competencies to be acquired or grown within the organisation is a delicate balance between reduction of the resources per core competency below the critical mass and leaving the enterprise vulnerable. Since there are no clear guidelines in the literature for identifying core competence and measuring their effectiveness, the initial set of core competence will have to be refined over a period of time by a process of continual learning and application to core product development. One type of assessment is bench marking the level of expertise of the organisation against that of the competitors.

Core competencies are not always strictly technology-based and therefore, they are generally classified into technology-based (antenna, technology), nontechnology-based (defining end user values) organisation culture-based (quality) and discipline-based (system design) categories. The technology-based core competency may be located in a single group whereas organisation culture-based type may be distributed throughout the organisation. The key resource for success of the core competency management is, of course, the availability of talented individuals. They should be selected on the basis of their intimate knowledge of the activities of the organisation, proficiency in the basic skills constituting their core competency area, their desire to innovate and their ability to operate within the matrix organisation.

The implementation of core competency in an organisation takes place by formulating a clear articulate strategic goal. It is less precise with respect to future end-products because it has to be sustained over a period of time that covers several generations of end-products. The strategic goal has to be overarching so that the organisation has to stretch itself to reach it. Some examples of strategic goals set by well known companies are, convergence of computers and communications (NEC), imaging (Kodak), world class copiers (Canon) and encirclement of Caterpillar (Komatsu).

The next step is the selection of core competencies. This is carried out by a combined team of functional specialists and the project staff whose experience, knowledge and understanding of the user market is brought to bear upon the evolution of a consensus on the basic skills and combination of basic skills in respect of current and future end-products. The same team will assess and evaluate the skills possessed by the organisation and the existing core competencies in terms of skills and those that are needed to be built or to be acquired by the organisation are clearly spelt out.

Once the strategic architecture outlining the strategic vision in terms of existing competencies and others to be acquired/developed is accepted, it is necessary that the organisation take steps to protect, safeguard and reinforce the existing core competencies and to use their framework to identify core products. Simultaneously, it is necessary to monitor contingencies so that advance warning of adverse effects are made known and a response is triggered, within the strategic framework. It is also necessary to foster a culture of free flow of technical, human and information resources between the project groups to maximise the return on people embodied skills. The fostering of such a culture is important, because over a period of time it becomes a source of intrinsic motivation and behaviour modification with sustained long term effect. The R&D organisation would now be transformed into a cluster of core competencies rather than a hierarchical structure with project or matrix base. The core competency management is distinctly superior to the present structures of R&D organisation because the core product acts as a balancing mechanism between the long time frames of core competence and the short time needs of end-products.

11. INDIAN SCENARIO

By virtue of immediate past, R&D in India has been confined mostly to governmental departments such as the CSIR, DoS, DRDO, DAE, academic institutions and public sector industries. According to published data, the national R&D investment for the year 1990-91 was Rs 4186 crore which works out to be 0.89 per cent of the gross national product. Of the total national investment in R&D, over 30 per cent of it is allocated to the DRDO, DoS & DAE from which the spin-off in the commercial sector would be marginal. Even though 87 per cent of the 1361 industrial R&D units are in the private sector, their investment does not amount to more than 12.6 per cent of the national total. The average investment per R&D unit by the private sector works out to be 0.65 crore whereas it is Rs 3.35 crore for the public sector whose R&D units are larger. In terms of sales turn over (STO), the R&D investment by the private sector works out to be 0.66 per cent. For the year 1992-93, the R&D expenditure as part of the STO was 0.57 per cent whereas it was 0.6 per cent for advertising and 6.44 per cent for new plant and machinery. The statistics clearly bring out that industry in India has by and large accorded lowest priority to R&D activities.

Until now, the funding for Exploratory R&D activities has come from the Government of India. As the returns on such investments are not directly measurable, commercial enterprises will not be interested in providing financial support. Even in the US, contrary to what national ideology and public rhetoric would lead us to believe, the US government has supported and more importantly influenced the direction and growth of technology in generating the 'generic knowledge'. This support served as a solid substratum for technological innovations and development by the industrial enterprises. Integrated circuits and computer networking are two of the most well known examples[23]. The government of India wi have to continue to be the major contributor of funds for scientific research and Exploratory R&D activities.

Even though in India, the government has recently taken measures to provide incentives to the industries to invest in R&D activities at academic institutions by granting 125 per cent tax write-off, it is not expected that this will spur the Indian industrialists to make use of this measure and build closer links with the academic institutions. To day, by and large research activity in advanced academic institutions has followed its own pattern usually with little relevance to the demands for solutions to the country's needs of technology development. The academic scientist places the greatest strategic value on the development and maintenance of state-of-the-art internal capability in scientific/technical fields which have global importance, because these are presumed to provide the ultimate assurance of new intellectual opportunities and challenges. By contrast, the industry reflecting a more traditional approach looks to markets as a more obvious and direct source of business opportunity. The differences between the academic scientist and the industry manager are not only in terms of the sources of future plans but also in time scales.

A second aspect which also may prevent closer interaction, arises as a result of replacing the traditional pipeline model, which is a sequential conceptual framework for the innovation process from invention, innovation to product development by the interactive model. It considers innovation as an integrated process from the time an idea is conceived till the time the product is introduced into the market. The innovation process is described in terms of three main functional areas, namely, research (basic and exploratory), technical (development, engineering, production) and commercial(marketing, sales, distribution and services). One of the best examples of this model is Xerography in which there was constant interaction between marketing, research and technical functions to reach the present level from the basic invention of Chester Carlson[24].

Strategic R&D activities leading towards specific application or applications are best attempted in the chain of laboratories set up by the central government under various ministries, and in some industry sponsored cooperative R&D institutions. Here again, the funding today of projects at these institutions will have to be by the government. In the case of the mission oriented departments such as the DRDO, DAE and DoS, projects are initiated in close association with users who are knowledgeable about their future requirements. The Strategic R&D activities are aimed ultimately to develop components/subsystems, systems and processes with technology as the main differentiator. One of the main reasons for the success of the mission-oriented government laboratories is an early commitment by the user for possible utilisation. Such a commitment in the commercial sector requires to be encouraged if the capabilities of the government R&D laboratories are to be fully exploited for building competitiveness by our industries.

There are several possibilities of linkages between R&D laboratories and industry and these can be listed in the order of increasing interaction and involvement by the R&D as follows[25].

(a) providing specialised analytical facilities including specialised laboratory facilities to the industry,

(b) making available to the industry the specialised trouble-shooting capabilities,

(c) development of alternate raw materials,

(d) development of analytical and quality control methods for specific products/processes,

(e) specialised testing of plant, equipment and machinery,

(f) design and development of special software for process control and production,

(g) design of process equipment,

(h) development and fabrication of product prototypes,

(i) process redesign for updation and better efficiency, and

(j) pilot plant scaling up of laboratory processes.

While some of these are already being exploited, there is ample scope to enlarge these activities. To ensure greater success for such liaisons, there is a need to establish an interface between the government R&D laboratory and marketing groups of the industry to carry out the functions of forecasting, evaluation and for providing strategic planning data about the likely customer preferences, technological options and production changes. This is very crucial to the success of the competitiveness of the industry as it involves not only the knowledge of the current and immediate future needs but also ability to detect the latent and unsuspected market needs that may arise out of changes in economic status, political and social developments. With these inputs both R&D and the industry will have to draw their plans for Strategic R&D activities.

As far as Short-Term R&D is concerned, in the case of mission-oriented departments, these activities are carried out by the institutions involved in Strategic R&D. These include product design, hardware/software realisation, product evaluation and testing so that the capability of the product is proved and the integrity of the design specifications during manufacture is assured.

Except for a handful of industrial houses, there are no other industrial R&D groups which can take up Short-Term R&D activities in our country today.

This is one of the main reasons why the results of R&D from the government laboratories do not find their way in the industries which resort to import of technology from abroad. These capabilities have to be built in-house by the large industrial enterprises, and for small and medium industrial houses the German pattern of industry association research laboratories would be a better bet.

There has to be a shift in emphasis in the R&D laboratories from individual projects to a set of projects to reap the benefits of possible synergies that can be developed over different functional and project groups. The R&D laboratories would be required to reorganise by having an overlay of the three groups, namely, core competency, core product and end-product. They have to closely interact with each other for meeting the organisation goals, with each group having the autonomy through authority and resources to pursue their own development goals within the broad envelope of the strategic goals. In actual practice, there has to be a continual tradeoff of resource allocations between end products, core products and core competence based on the consideration that core competencies selected to attain the strategic goals of the organisation provide the most salient guide posts for the selection and development of new core and end-products.

12. CONCLUSIONS

Technology management in our country is still in its infancy. Our industries as well as the R&D organisations have to understand the changing nature of technology management and the complexities of the intense competitive environment. Since the technology and the product life cycles are shrinking, and the sustainability of competitiveness has assumed importance, the newer concepts of technology fusion and core competence framework for strategy requires a closer interaction between the scientists and the managers of industry. Indian industry can no longer remain indifferent to R&D if it has to compete with foreign companies for a share of the international and the domestic market. The State also has a positive and definitive part to play in bringing the industry and R&D together to gain and sustain the competitive edge.

REFERENCES

1. Dollar, D. & Wolff, E. N. Competitiveness, Convergence and International Specialisation. The MIT Press, Cambridge, 1993. p. 177-88.
2. Degregori, T.R. A theory of technology. Applied East West Press Pvt. Ltd, New Delhi, 1989. p. 56-66.
3. Evanson, R. & Westphal, L.E. Technological change and technology study, Unitech Working Paper #12. Institute for New Technologies, The United Nations University, Maastricht, 1994. p. 141.
4. Ernst, D. & O'Connor, D. Technology and global competition: The challenge for newly industrialising economies. Oxford & IBH Publishing Corporation, New Delhi, 1989. p. 48-75.
5. Lowe, J. & Crawford, N. Innovation and technology transfer for the growing firm. Pergamon Press, Oxford,1978. p. 30-47.
6. Rosegger, G. The economics of production and innovation. Pergamon Press, Oxford, 1987. p. 109-27.
7. Coombs, R.; Saviotti, P. & Walsh, V. Economics and technological change. Mcmillan Education, London, 1987. p. 93-134.
8. Cho, D.S. From subsidizer to regulator, the changing role of Korean Government. *Long Range Planning,* 1992, 25(6), 48-55.
9. Biondi, L. & Galli, R. Technological trajectories. *Futures,* 1992 (July/August), 580-92.
10. Smith, P.G. & Reineretsen, D.G. Shortening the product development cycle. *Res. Tech. Mana.,* 1992 (May/June), 44-49.
11. Gaynor, G.H. Exploiting product cycle time. *IEEE Transactions EMR,* 1993 (Spring), 30-43.
12. Popper, E.T. & Buskirk, B.D. Technology lifecycles in industrial markets. *IEEE Transactions EMR,* 1993 (Spring), 44-50.
13. Zahra, S.A.; Nash, S. & Bickford, D.J. Creating a competitive advantage from technological pioneering, *IEEE Transactions EMR,* 1994 (Spring), 76-84.
14. Utterback, J.M. Mastering the dynamics of innovation. Harvard Business School Press, Boston,1994. p. 24-55.
15. Steele, L.W. Technology maturation and technology substitution. *IEEB Transactions EMR,* 1990 (March), 11-24.
16. Kasturirangan, V. & Bowman, G.T. Beating the commodity magnet. *IEEE Transactions EMR,* 1994 (Spring), 32-38.
17. Werther, W.; Berman, E. & Vasconcello, E. The future of technology management. *IEEE Transactions EMR,* 1994 (Fall), 13-19.
18. Kodama, F. Technology fusion and the new R&D. *IEEE Transactions EMR,* 1992 (Summer), 6-12.
19. Prahalad, C.K. & Hamel, G. The core competence of the corporation. *IEEE Transactions EMR,* 1992 (Fall), 514.
20. Prahalad, C.K. The role of core competencies in the corporation. *Res. Tech. Mana.,* 1993 (November/December), 40-47.
21. Band, D.C. & Scanlan, G. Strategic control through core competencies. *Long Range Planning,* 1992, 28(2), 102-14.
22. Hamel, G. & Prahalad, C.K. Competing for the future. Harvard Business School Press, Boston, 1994. p. 27-47.
23. Methe, D.T. The effect of innovation on market structure. *IEEE Transactions EMR,* 1991 (Winter), 18-30.
24. Mort, J. Xerography. A study in innovation and economic competitiveness. *Physics Today,* 1994 (April), 32-38.
25. Colombo, U. & Galli, R. (Eds). Planning research and development. Wiley Eastern Ltd, New Delhi, 1995. p. 140-64.