Business Operation and Technology Strategy

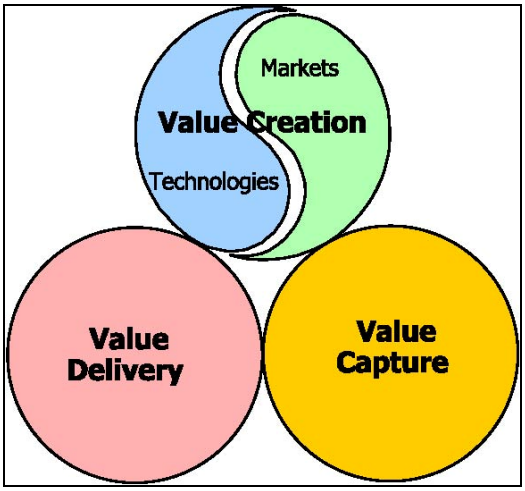
Besim Ćulahović, University of Sarajevo Faculty of Economics and Business Administration, Sarajevo, B&H
Zvonko Brnjas, Belgrade Banking Academy, Belgrade, Serbia
JEL: L2, 032

Technology strategy: some key elements

Defining technology strategy: key foundation and questions

Conventionally, the broad objective of technology strategy is to guide a firm in acquiring, developing and applying technology for competitive advantage. A firm's technology strategy is also expected to serve its overall strategy in developing and exploiting firm specific advantage. In this sense, it is contingent on the firm to ensure a consistency between technology and business strategies. The economics literature has emphasized the role of technological capabilities in acquiring and sustaining firm level competitive advantage. These capabilities broadly relate to the ability of firms to handle technologies and cope with technological change; the ability to absorb and build on technologies. In this context, building such capabilities should be the focus of strategic technology management endeavors.

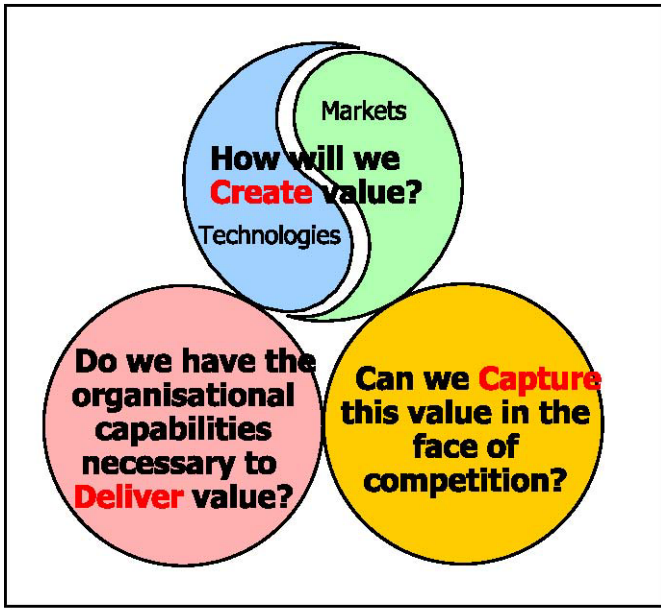
Figure 1. Three foundation of Technology strategy



At the firm level these strategic choices get translated into a variety of decisions which cut across functional boundaries. Need assessment, make-buy choices, identification of the technology and its source, selection of the collaborator if joint development is involved, levels and timing of R&D and associated investments etc. are all part of this complex decision process. Studies have shown that formulation and implementation of technology strategy are constrained/determined by a variety of features which distinguish technological

activities from other activities and one industry/firm from the other. Following a recent analytical review of these issues, we summarize some of these features here.

Figure 2. Three key questions of Technology strategy



Effective technology strategy rest on three foundations: a) value creation, b) value capture and c) value delivery, i.e. on answers to these three key questions (see figures 1 and 2). The foundations and questions build capability to maximize value and profits. More formally, a technology strategy as a choice of capabilities to maximize profits given that:

- Profit is a function of value delivered and competitive offerings,
- Value delivered is a function of product attributes (in the broader sense),
- Product attributes are a function of technical capabilities and value chain,
- Technical capabilities are in house capabilities and partner skills, in an environment in which many of these relationships are not fully characterized and in which they will probably all change over time.

So, a central part of effective technology strategy is to use of effective tools to understanding evolution:

- The S curve and Dominant Design
- The evolution of markets
- Understanding competition
- Who will make the money?
- Appropriability and complementary assets
- Exploring organizational competence
- No one best way: organizational competence as a key strategic choice
- Putting the pieces together: the evolution of competition and competence over the life cycle.

Formulation of technology strategy

Technology is at the core of systems designed to satisfy societal or customer needs. Companies are formed to provide a structure and a mechanism that facilitate the spinning out of technology to satisfy those needs. When a company has a vision and develops its mission statement, it is stating the reasons the company exists and the inherent values of the company. When the company develops a strategy and its associated plans of action, it creates the vehicle that moves it toward the fulfillment of its mission and the attainment of its vision. The purpose of business strategy is to gain a sustainable economic advantage. The purpose of technology strategy is to gain a sustainable technological advantage that provides a competitive edge. The two strategies must be closely intertwined and highly integrated. This requires extensive forethought about the firm's distinctive technologies, the products or services it can provide, the potential customers, and where the organization wants to be in the future. The company's technologies must be harnessed and exploited according to a well-designed plan. Effective technology management is based on successfully linking business and technology strategies.

Technology strategy is concerned with exploiting, developing, and maintaining the sum total of the company's knowledge and abilities. Many organizations still seem to underestimate technology's importance.

There are many factors that determine business success; although technology is a very important one, it is not in itself sufficient to ensure business success. Good business is about integrating technological innovation with production, marketing, finance, and personnel to achieve established goals.

Two commonalities among companies that use technology as a competitive weapon are:

1. Management views technology as a major competitive weapon but does not emphasize it at the expense of other areas.
2. The criteria used to support any project consist of (a) whether the project supports the business goal, (b) whether the project protects and/or establishes technological leadership, and (c) whether the project solves customer problems.

Technology gives a company a competitive edge. Corporations with inferior technology cannot compete with corporations utilizing superior technology. However, to use technology as a competitive weapon, managers must manage it as part of the business system.

Michael Porter advocates that technology strategy be formulated within the larger context of business planning. Porter's approach to formulating a competitive strategy is to concentrate on optimizing the efficiency of the value chain. This implies developing and maintaining a competitive advantage by finding the most effective means of carrying out all the activities of the business process so as to offer the customer long-term value. Porter proposes that a technology strategy be formulated using the following steps:

1. Identify all the distinct technologies and sub-technologies in a value chain.
2. Identify potentially relevant technologies in other industries or under scientific development.
3. Determine the likely path of change of key technologies.
4. Determine which technologies and potential technological changes are most significant for competitive advantage and industry structure.

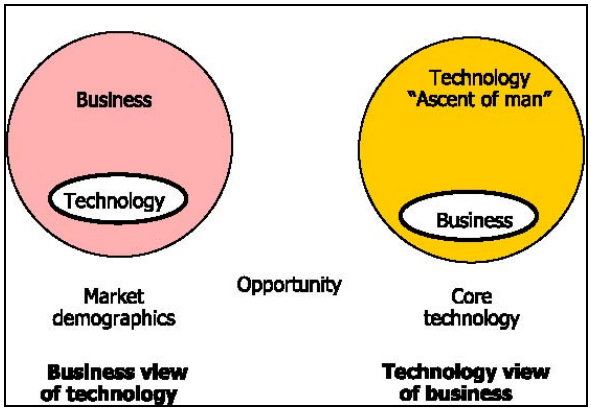
5. Assess a firm's relative capabilities in important technologies and the cost of making improvements.
6. Select a technology strategy, encompassing all-important technologies that reinforce the firm's overall competitive strategy.
7. Reinforce business-unit technology strategies at the corporate level.

Linking technology and business strategies

Business success depends on the products or services brought to the market. As previously indicated, these have their base in technology. Organizations that know how to link their technology strategy with their business strategy will be more competitive in the global marketplace. The first step toward integrating business and technology strategies is to get the business and technical sides of corporate management to agree on a common

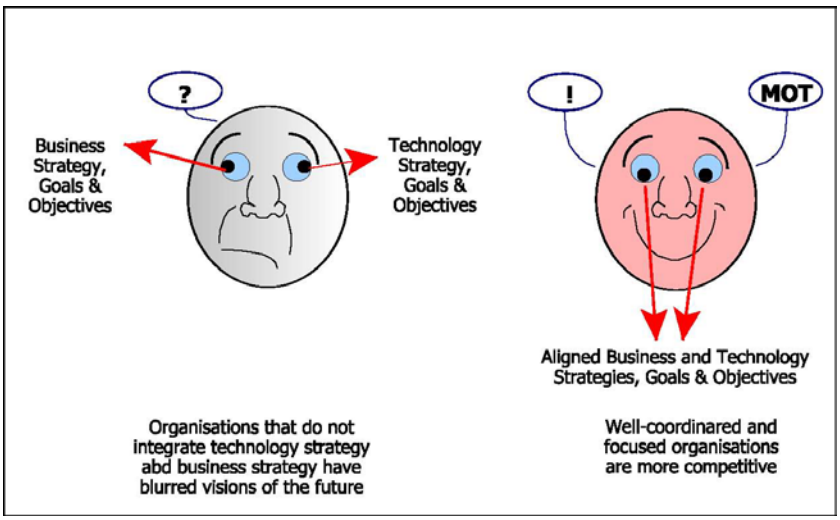
Usually the business and technology strategies side perceives technology as a subset of business, while technologists perceive business as a subset of the general technological ascent of human beings, as shown in Figure 3. On one side, technology is a subset of a business enterprise. Market demographics influence the success of the business. Here, businesses tend to identify technologies relevant to creating business opportunities that satisfy market demands. On the other side, technology, through its role in the ascent of human beings, is the influencing factor in creating business. Business becomes a subset of technological advances that create significant opportunities for companies. For optimal results both sides must be integrated into one organizational strategy. Metaphorically speaking, integrating technology strategy and business strategy can be thought of as two sides of a coin: Either side is worthless without the other.

Figure 3. Framework for formulation of business set of priorities



Companies that have a one-eye view toward business-oriented functions, such as finance, accounting, marketing, and sales, may face technical obsolescence or miss out on potential growth and profitability. Similarly, companies that focus entirely on technological development without effective strategy for exploiting the technology in a timely manner may not be able to sustain profitability. Management must be able to align its technology and business strategies to focus on achieving its goals and objectives. An interesting illustration of this concept is shown in Figure 4.

Figure 4. Integration of technology and business strategies



The technical community tends to hold the view that technical achievements by peers around the world often provide a more reliable guide to the future than do formally documented business forecasts. By contrast, the business-planning community usually looks at markets and other external trends as a more obvious and direct source of business opportunity. These two perspectives need to be reconciled. The linkage between the goals and objectives of the corporation and its technological strategy is very important. Broad consensus and understanding must exist between business and technical managers throughout a company. A number of generic questions that should be addressed by strategic planners on both the business and the technical sides of the house:

What new strategic options will technologies provide?

In responding to these questions, a company can develop relationships among its high-level strategies, its lines of business, and the technologies that are needed to achieve business goals. A company can then proceed to develop the product-technology-business connection.

Technology strategy features

Nature of technology and innovative activities

Few of many inter-related features of technology, technological change and innovative activities identified in the literature, which can impinge on firms' technology strategies are discussed here.

Tacitness: A significant part of knowledge developed by enterprises is tacit; it is difficult if not impossible to codify. This is particularly the case in the early phases of technology development and where circumstantial specificity is high. While it is difficult to make a general statement, among the three Ps, practice is likely to most tacit in nature. Tacitness has significant implications for the transfer and appropriability of technology. Broadly, as tacitness of a technology increases, appropriability goes up but transfer becomes increasingly difficult, requiring significant efforts on the part of the buyers and sellers of technology.

Differentiated and Cumulative Nature of Learning: Innovation related activities are highly differentiated. Specific technological skills in one field (e.g., developing pharmaceutical products) may be applicable in closely related fields (e.g., pesticides), but they are of little use in other fields (e.g., designing automobiles). Besides, technological change is often incremental in nature based on continuous cumulative learning; discrete/ quantum changes in technology are few and far between. However, the degree of specificity and cumulativeness may differ across the three Ps and firms may consciously need to ascertain if learning on any one of the Ps could be generalized across technologies within the organization. Cumulativeness like tacitness adds to appropriability of technology.

Technology Supply Chain: Technological inter-relatedness plays a crucial role in technological development. Linkages with upstream and downstream technologies (users) may hinder or induce technological change in a segment (see below). Such a network of "linked" innovators or the technology supply chain may also be important in another way. Often, the full benefits of new technologies are not reaped because all elements associated with the technology are not adequately implemented within the organization; product, processes and practices linked to a technology need to be embodied in the organization for good results. Traditionally, technology development has been analyzed within the boundaries of a firm. The role of input-output linkages the firm has with other entities is usually ignored. Suppliers of products and processes are, at best, seen as "borrowed blue-print makers" who would fabricate only on the basis of given designs. The problem with this approach is that innovation is viewed as a compartmentalized and discrete activity. However, empirical evidence suggests that successful development of technology, either in the form of products, processes or practices, has often involved interaction of firms across industrial sectors. Technology development in these supply chains takes advantage of the synergies of technological capabilities in their respective sectors. For example, improvements in weaving processes in a textile mill may call for a close interaction with a textile machinery firm which in turn may have to depend on the assistance of firms in machine tool and micro-electronics sectors. Technology supply chains form natural clusters for continuous improvement of products processes and practices. In economic terms, these technology supply chains can be seen to form the core incentive structures for technological activity. It is the joint interest of the suppliers and users of technology which induces continuous innovation.

Appropriability: Despite various legal provisions for protecting intellectual property, appropriability of an innovation is never complete. How far the results of the R&D activity be internalized and how far will they constitute a public good depends on a large variety of factors including tacitness, cumulativeness and complexity of technology, market structure and access to complementary assets. What is not appropriated by the innovating enterprise spills over? Technology spillovers in a sector determine the potential for imitation in that sector. We have already referred to the links between appropriability and technology specific features. It is the discussion of complementary assets that we now turn.

Complementary assets and technology strategy-manufacturing strategy interface

In all these decisions, which are expected to develop firm specific competitive advantages, the issue of complementary assets will have to be tackled. In the absence of such assets, which include manufacturing and distribution capabilities, appropriation of new technologies may be rather limited. The earlier literature analyzed the role of complementary assets in the context of the technology life cycle: In the initial phases of new technology commercialization, competition is among designs. Uncertainties are about which design will emerge as dominant. It is of strategic relevance in this phase to make efforts to create the dominant (standardized) design closer to firm's specification. After the emergence of the dominant design, price (and delivery) competition becomes more relevant. Consequently, reduction in costs through process innovation, scale economies and learning becomes crucial. These processes get reflected in the empirical observation that when new technologies are commercialized, process innovation often follows product innovation. With the slowing of the rate of product innovation, designs tend to become more standardized, providing the opportunity for large scale production and the deployment of specialized assets.

While this perspective on the technology life cycle is instructive, it implicitly assumes that a breakthrough innovation underlies this transition. Recent developments and the success of the Japanese firms, especially in the auto sector, have challenged this linear-dichotomous (product versus process innovation; design versus price competition) characterization of the processes at work. Even during the phase of process innovation, significant product innovations may take place; firms compete on new variations of the old designs with significant reductions in lead times. Within the broad technology life cycle, product life cycles are increasingly becoming shorter with high rates of product obsolescence. Besides, both product and process innovations may require simultaneous attention for reaping full benefits of product innovations as an exclusive focus on product innovations may delay. Complementary assets can be generic, specialized or co-specialized. Generic assets are general purpose assets that do not need to be tailored to the innovation. Specialized assets are tailor-made for the innovation, and are necessary for the implementation of the innovation. Co-specialized assets are those for which there is bilateral dependence.

In any case most developing country firms are usually not dealing with breakthrough innovations. Therefore the role of complementary assets needs to be analyzed in a different context. In almost all cases, the successful commercialization of an innovation requires that the know-how embodied in the innovation be utilized in conjunction with such complementary assets as competitive manufacturing, marketing and after sales support. Whether the assets required for least cost production and distribution are specialized is important for strategic decisions regarding integration and collaboration. It has been suggested that when managers make R&D and commercialization decisions, they must identify, preferably ahead of time, the complementary assets that the innovation will need for success full commercialization. Contractual or collaboration alternatives will make strategic sense if the complementary assets are not specialized, or if the appropriability of the innovation is ironclad.

Collaboration/contract modes can also be acceptable if (i) the required complementary assets are not critical; or (ii) for assets which cannot be procured by the innovating firm due to lack of financial resources; or (iii) for assets in which imitators are already irrevocably better positioned. Otherwise, the integration (in-house availability of complementary assets) alternative ought to be preferred to capture the value of the innovation. Given limited appropriability of technology, strategies that employ co-specialized assets and other interdependencies are advocated to generate and protect the economic rents from innovation.

Manufacturing capability is often seen as one such asset. Empirical evidence has shown that competitive manufacturing provides significant learning potential and the associated cost, quality, delivery and flexibility advantages. Just like successful commercialization of certain innovations is dependent on access to good manufacturing facilities, nature of existing manufacturing facilities can condition nature of innovation activities (even technology strategy) undertaken by the firm. Competitive manufacturing is also likely to be critical in many circumstances because technology and product (and industry) life cycles are not co-terminus; a given embodied technology may be able to provide various generations of new products. As the technology moves from early design to the stable stage, manufacturing ought to move through job shop, batch and continuous process modes. Depending on product variants and volumes, the focus of the manufacturing facility, capacity levels, and manufacturing infrastructure changes to meet the strategic technology needs. This, in essence, characterizes the manufacturing strategy of a firm. Sometimes, production capabilities provide strategic choices for in-house innovation for new product and process introduction.

Industry characteristics

Observed sectoral patterns of technical change are often seen as a result of the interplay between various kinds of market inducement, and opportunity and appropriability combinations. Structural and technological characteristics of industrial sectors affect opportunity and appropriability conditions and therefore, impinge on technological strategies of firms in these sectors.

Structural Features: Competition involves rapid imitation with innovations continuously superseding each other. Therefore, there is incentive to innovate only if one feels confident of being able to exploit that innovation rapidly. Monopoly or imperfect competition provides a better setting in which to exploit innovation. The Schumpeterian view is that monopoly power and large size of the firm facilitate/induce technological advance. This is so because the large oligopolistic firms are better able to internalize the benefits of innovation and are generally more certain of their environment. Such firms have the wherewithal to exploit new technology quickly largely due to better access to finance and complementary assets like manufacturing facility and capacity and marketing infrastructure. Therefore, oligopolistic industries are expected to be more innovative. Empirical studies, however, have not been able to discern any neat pattern of linkages between market structure and technological activity. While the importance of complementary assets cannot be denied for any innovation, the Schumpeterian logic is probably more apt for breakthrough innovations rather than continuous improvements of the Kaizen variety. It is not clear if the empirical investigations

are able to make a clear distinction between these two types of innovations. Furthermore, differences across and within industries in terms of product/industry life cycles, can complicate empirical investigations. In any case, the implications of market structure may differ for the three Ps of technology: oligopolistic power may not be required for changes in practices and many incremental process (even product) innovations. The firms, especially in the developing countries, need to recognize such opportunities and benefit from them.

Technological Features: Many studies have emphasized the existence of significant inter-sectoral differences in the nature, sources, determinants and objectives of innovative activities and resulting innovations. On the basis of sectoral specificities observed in developed countries, Pavitt has identified five categories of these sectors: supplier dominated, specialized suppliers, scale intensive, science based and information intensive. Broadly, as compared to other sectors, technological opportunities are higher in science based firms (given munificence in underlying technologies) and in specialized suppliers (given continuous pressures to improve production efficiency in user sectors). The information intensity of many sectors is on the rise. It should be emphasized that these are not watertight categories and a firm may show features of more than one category. Besides, the characterization of these sectors can change over time. While the importance of product and process innovations may differ across sectors, the relevance of practice innovations is likely to be high in all the sectors.

Firm characteristics

A large variety of firm characteristics, impinging on technology strategies have been highlighted. It is not our purpose required to cover all these features; only a few points are made. The role of firm size has already been highlighted above. We only wish to re-emphasize that large firms are often able to internalize the benefits of innovation because of the access to complementary assets which include competitive manufacturing facilities, distribution and service networks and complementary technologies. A multi-product firm has opportunities for economies of scope based on transferring technologies across product lines and blending them to create new products. Despite the path dependent nature of technological change, the diversity of application areas for a given technology is often quite large, and it is often feasible and sometimes efficient to apply the firm's capabilities to different market opportunities. A multi-product firm, therefore, may have the opportunity to widely diffuse the innovations in the three Ps, especially practices.

Firms commonly need to form external linkages, vertical (both upstream and downstream), lateral, and sometimes horizontal in order to produce and market their products. For example, linkages are extremely important when there is vast consumption In Supplier-Dominated Sectors, innovation is exogenous to the sector and is embodied in purchased inputs. R&D is low and mainly adaptive due to limited technological opportunities. Firms in the Specialized Suppliers sector focus on product innovations that enter other sectors as capital goods. Formal R&D is low but abundant innovation opportunities are exploited through tacit design and engineering capabilities. Innovation is endogenous to the Scale-Intensive Sector as part of production activities in large complex production systems. Production engineering and learning-by-doing are major sources of technology. R&D expenditure is high as these forms generate their own process technology

in many cases and integrate vertically to make their own equipment. Innovation activity is endogenous to the Science-Based Sectors also but is located in labs and based on rapid developments in underlying sciences. Technological opportunities are high resulting in high R&D expenditures. Product innovations from this sector enter a wide range of sectors as capital or intermediate inputs. Technological accumulation in information intensive firms comprises the design, building operation and improvement of complex systems for the storage and processing of information. Improvements are incremental and experience based and emanate from operating experience in large user firms and suppliers of systems and application software.

Technology policy and its links with technology management

Technology policy in transition

Most advanced countries have established sets of policies which are directed towards the national capacity to produce and utilize technology in the interests of social and economic development. These include, most notably, incentives such as subsidies and/or tax concessions for firms investing in R&D or hiring research and engineering personnel. Although their roots can clearly be traced to science policies and they still share some of the same types of instruments, technology policies are now considered to fall into a specific and separate policy area. They tend to embody distinctive objectives (most notably the advancement of industrial competitiveness) and address particular problems (such as the uptake and utilization of technology by industrial firms). They reflect a perception that the world of technology, which is mainly the province of firms searching for profits, follows rules which are rather different from that of science, despite the fact that the two worlds are intimately associated and mutually dependent on one another.

Technology management: the emergence of the concept

The concept of technology management draws on the same roots as contemporary technology policies. Reflecting the principles, technology policy into the private sphere, technology management sees technology as a core strategic resource, with many systemic characteristics, which must therefore be considered from an integrated perspective. On the part of firms, technology management serves to ensure that the synergies between different technological capabilities and applications are fully exploited, and that the organization, skills, and other associated factors are in place to optimize the value of these resources. This obviously requires a sophisticated understanding of the nature of technology and the determinants of technological change.

Like business strategy more generally, technology management can be seen as a function at the interface between a series of bottom-up and top-down processes of organizational development, both of which serve to emphasize the growing importance of technology as a component of the way business is done. Technology management is the point at which long-term visions of research at short-term (continuous) improvements in products and process meet (see Figure 5).

Figure 5. Technology Management: where long-term visions and short-term improvements meet

The search for improved performance of existing business processes has, on the one hand, brought together methods at technologies that were previously separate: total quality management, just-in-time logistics, electronic data interchange, CAD-CAM, management information systems, etc. These partial improvements are being increasingly integrated into more comprehensive approaches requiring a strategic orientation over the enterprise as a whole: lean production, computer-integrated business, business re-engineering.

On the other hand, there is growing appreciation of the need to link research and development more closely to the long-term needs of the enterprise. This has led to a number of management approaches which link the firm's overall business strategy with its technological capabilities. The concepts of 'core competence' and 'core technology' are illustrative of this trend. Firms are increasingly thinking of technology not just as an internal factor which forms a major element of their specific competitive strengths, but as a means to leverage external capabilities, via strategic alliances and joint ventures.

An important impetus towards the technology-management approach comes from the lessons of failure in accommodating to technological change. Heavy investments in new production technology were made by firms in the 1980s with little understanding of their operational and strategic implications. They were driven by the perception that easy gains in productivity could be captured by introducing high technology automation such as robotics, and supported by various government initiatives. The widespread failure to realize the anticipated benefits has been well documented, and the lessons learnt have been a determining factor in developing the more sophisticated approach to technology associated with the notion of technology management. Technology management implies a movement

from considering technology in functional terms or in relation to individual business processes, towards an overall appreciation of technology from a corporate perspective. It also reflects an appreciation that the fundamental and distinctive competences of firms are not static features which relate only to their present products and processes, but that they have important dynamic characteristics, at the same time allowing an accumulating innovative capability, but also constraining the direction of their future competitive development.

The rationale for technology management

The essential factors which make technology management so important for firms are fourfold:

First, the widespread and diversified impact of technology on competitive performance - In practically all areas of business, technology has become a dimension on which firms are able to differentiate themselves from their competitors, whether their strategies relate to price, quality, speed to market, or other aspects of competition. This is no less true of service than manufacturing sectors: the information revolution has ensured that sectors like telecommunications and financial services are amongst the most technologically dynamic. Neither is the phenomenon restricted to high-tech industries; the sectors just cited, for example, carry out relatively little research of their own, and there are innumerable examples of where astute introduction of new process technologies has rejuvenated industries once regarded as mature. Technology management fills the need for a much broader concept than research management, which is relevant to the complete range of processes within the firm and practically all types of firm.

Second, the interdependence between technology, knowledge and skills. What the failures of the 1980s demonstrated above all was that the level of performance of complex technological systems is not an attribute of the hardware alone. Understanding and making use of the full potential of investments in technology depends upon complementary investments in the knowledge and skill of the people making use of the technology. This goes well beyond the workforce directly associated with the technology in question, and may affect all levels of management. The specific knowledge necessary to master complex technologies in a specific business context is rarely widely available, and accumulates only slowly. This means that firms are closely bound to the development paths that their previous history has prepared them for, and their business strategies need to be based on an understanding of the limitations of their own technological capabilities in the face of radical changes in the technological basis of their industries.

Third, the organizational implications of technological change - Exploiting in-house technological resources in the development of new products and processes depends upon an organizational capacity to transcend functional and divisional boundaries and thus bring together research activities from different product areas and put them in close contact with development and marketing activities, etc. Exploiting external sources of technology, on the other hand, can demand a capability to transform production processes to take advantage of the new possibilities opened up by the technology. Emerging management paradigms such as ‘lean enterprise’, 'core competence’, 'business process re-engineering’, and so on, can be seen to involve both organizational and technological components, closely linked.

Fourth, the limits to technological autonomy enjoyed by firms **-** The complexity of modern technologies and their intrusion into all aspects of business mean that even the largest and most technologically advanced firms depend quite extensively on technology sourced from outside. All firms face the need to monitor technological developments undergone by their suppliers, customers, and competitors. Increasingly, firms are thinking of leveraging their own technological capabilities by combination with those of other firms, through strategic alliances, joint ventures, and more informal networking arrangements. This brings additional organizational and skill-related problems internally, to manage a variety of external interfaces and assimilate the knowledge arising from them, whilst protecting against leakage of the firm's own intellectual property.

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