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THE MANAGEMENT OF TECHNOLOGICAL INNOVATION IN BUSINESS

Ben Dankbaar
Nijmegen Business School. University of Nijmegen

The adequate mangement of technology in the enterprise is an important precondition for the optimal use of knowledge and technologles, which are often available but underutilised. Technology management is the point where short-term improvements in products and processes are linked to long-terms visions of research and development. After a discussion of the place of technology mangement in current business literature, the paper provides a brief overview of the methods and instrument for technology management. It is emphasised that technology management requires no just technological competence, but also entrepreneurial competence and learning ability. In this perspective, technology mangement is closely intertwined with strategic management, i.e. with the choices made concerning the position of the organisation in relation to its competitors.

Teknologiaren kudeaketa eraginkorra aldez aurreko baldintza nahitaezkoa dugu ezagupenaren eta teknologien erabilera onena lortzeko, epe motzerako produktu eta prozesuen hobekuntzaren eta epe luzerako ikerketa zein garapenaren arteko bilgunea dugu teknologiaren kudeaketa. Artikuluak, teknologiaren kudeaketak egungo bibliografia ekonomikoan duen tokiaz eztabaidatu ondoren, teknologiaren gestiorako bide eta tresnen berrikuspen laburra ematen du eta, gaitasun teknologikoen beharraz gainera, enpresa eta ikasketa gaitasunez dihardu. Ildo horretatik, teknologiaren kudeaketa eta gestio estrategikoa estuki loturik agertzen dira, adibidez, erakundeak lehiatzaileen aurrean duen jarrerari buruzko erabakiak hartzeari dagokionez.

Una gestión eficaz de la tecnología en la empresa es una condición previa esencial para la optimización del uso del conocimiento y de las tecnologías, a menudo disponibles pero infrautilizadas. La gestión tecnológica es el punto de encuentro entre la mejora a corto plazo de productos y procesos y las perspectivas a largo plazo de investigación y desarrollo. Tras un debate acerca del lugar que ocupa la gestión tecnológica en la bibliografía económica, insistiendo no sólo en la necesidad de competencias tecnológicas, sino también de competencias empresariales y capacidad de aprendizaje. En este sentido, la gestión tecnológica está intimamente ligada a la gestión estratégica, por ejemplo respecto a la forma de decisiones relativa a la postura de la entidad frente a sus competidores.

The translation of new knowledge into competitive products is one of the essential tasks of management. Indeed, according to Schumpeter, who introduced the notion of innovation into economics, the essence of entrepreneurship is bringing together knowledge of what is (technologically) possible with knowledge of what is needed. If the management of European enterprises does not succeed in making such «new combinations» of knowledge or if it is making them too slowly, the competitive performance of these enterprises will obviously decline. This can be considered as a failure of management and in particular of what we call «technology management». *If technological knowledge is available and not used, there is a problern of inadequate management of technology in the enterprise.*

Technology management encompasses all management activities associated with the procurement of technolo-

gy, with research, development, adaptation and accomodation of technologies in the enterprise, and the exploitation of technologies for the production of goods and services. Technology management is concerned with product technology, process technology and technologies supporting other business and management functions.

The aim of technology management is to maintain and improve the competitive position of the enterprise by the utilization of technology[1]. This obviously covers more than the relatively well-known function of R&D management. Rada has tried to summarize the difference in one sentence, saying that « R&D management is concerned with the use of resources for the creation of knowledge, whereas technology management is concerned with the use of knowledge for the creation of resources»[2]. This statement underlines correctly that technology management is concerned with the utilization of technology, but it may suggest incorrectly that R&D management should not be concerned with the specific uses of the knowledge that is created, R&D management is not so much opposed to technology management, but part of it. Technology management is the more encompassing activity. Among other things, technology management is about make-or-buy decisions in technological development. In that sense, it determines the agenda for the R&D department. It is also concerned with watching the long-term trends in relevant technologies, suggesting new fields of enquiry to the R&D department. It may also Identify the need to speed up current research in view of the technological performance of competitors.

R&D management is related to the presence of R&D activities in the enterprise. Technology management, however, is relevant even in the absence of in-house R&D. R&D management is usually seen as the main function of the heads of research laboratories. Technology management cannot so easily be identified with specific departments or persons. The various activities that are associated with technology management (see below) can be carried out by different persons in different departments. It should be clear, however, that these activities contribute to technology management as a strategic function, that belongs to the leadership of the enterprise, In large enterprises, somebody on the Board of Directors maybe in charge of technology management. In other cases, it may be seen as a collective responsibility of the board, or in small enterprises simply as an additional task for the general manager. However organized, the function of technology management is to ensure that the enterprise is profiting from technological change in an optimal manner, technology management should not be technology-driven: it should be business-driven,

THE CHALLENGES OF BUSINESS-DRIVEN TECHNOLOGY MANAGEMENT

The growing appreciation of the need for technology management is based on the awareness that competition has become increasingly intensive and increasingly based on the quick utilization of technology. It is no longer possible to rely blindly on the laboratory to come up with a new invention in time to keep the enterprise alive, Technological change in the enterprise has to be guided and managed consciously within the framework of an overall business strategy. Technology management has been (and is being) discovered in different enterprises in different ways. There are *two main roads of discovery,* that can also be recognized in the extensive business literature on the subject. In both cases, the main finding is the need to take an integrated, strategic view of the enterprise and its needs.

*On the one hand, there is a 'bottom-up' process, starting from the primary process and supportive functions in the enterprise. In the search for improved performance various methods and technologies are brought together that up till now were used separately from each other: total quality control, just-in-time logistics, electronic data interchange, cad-cam, management information systems. All these partial improvement methods are increasingly integrated in more comprehensive approaches requiring a strategic orientation on the future of the enterprise as a whole: e.g. *lean production, computer-integrated business, business re-engineering.* Together, these concepts are said to constitute a *'paradigm shift'* in the way business is done[3].

* On the other hand, there is a *'top-down'* process, involving a growing appreciation of the need to link researchand development more closely to the long-term needs of the enterprise. This has led to such notions as *strategic technology management* and *technology strategies,* which need to be derived from business strategies. The concept of *'core Technology'* has been developed to help enterprises define their core business. Instead of focusing on specific product-market combinations, firms are encouraged to think of all possible applications of their technological competence, even if this involves entering unrelated markets. Where enterprises focus themselves and their research on a limited number of core businesses and core technologies, the need for cooperation with other enterprises increases. This has given rise to such notions as *strategic alliances, the extended enterprise* and *co-makership. 'Third generation R&D management'* is called for as a new corporate level synthesis of long-term strategic research and division-level market-oriented applied research. At the operational level, this process involves the discovery of *simultaneous engineering* and *multidlsclplinary project teams* as techniques for making research more responsive to the needs of production and marketing (i.e. the customers).[4]

Technology management is the business function in which these two roads of discovery come together. *Technology management is the point where the long-term visions of research and the short-term (continuous) improvements in products and processes meet.* It is concerned with the technology needs of current and future businesses of the enterprise. As such, it is derived from the long-term strategic orientation of the enterprise. But it is also concerned with the implementation and application of available technologies in the short-term business of surviving in a competitive market place (cf. Figure 1).

Technology management has a *'tous azimuts'* perspective, monitoring technological change inside as well as outside the enterprise, concerned with core technology as well as with secondary technology, supporting the primary process of the enterprise as well as its supportive functions.

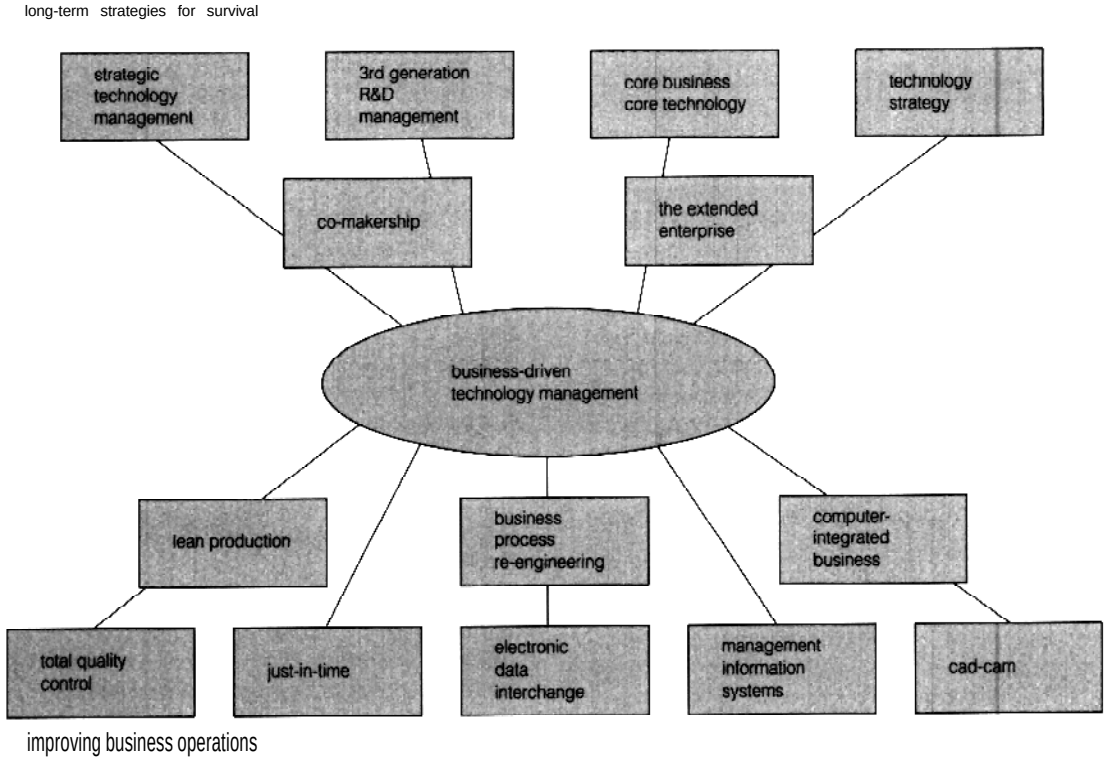
1. Although there is meanwhile a substantial literature on technology management, the concept is used in different ways by different authors. For an overview see Durand (1988); Dussauge et al, (1992).

2. Quoted in Chanaron (1991), p. 383

3. Womack et al. (1990) Johansson et al. (1993); Tapscott & Caston

4. Roussel et al. (1991); Booz-Allen & Hamilton; Prahalad & Hamel (1990); Granstrand et al. (1992).

FIGURE 1: **Where long-term visions and short-term improvements meet**



** Technology management is necessary in both technology-using and technology-producing enterprises, in small as much as in large ones.* All enterprises face the challenge of managing technological change. Technology-using enterprises are enterprises that absorb technological change primarily through their relations with suppliers of machinery and materials, often urged on by well-informed customers. Depending on the sector in which they are operating, technology-using enterprises may or may not dispose of in-house R&D activities. Technology-producing enterprises perform research and/or development and generate part of the technology they need in-house. The long-term performance of technology-using firms depends on their ability to quickly recognize and master new relevant technologies that are becoming available in their environment. It is less often recognized that this is equally true for the long-term performance of technology-producing firms. Every company, even if it is leading edge in its own field, needs to make use of technologies that originate elsewhere in order to be competitive.

** Technology management is concerned with core technology as well as with technologies that are sourced from outside.* The core technologies of the enterprise are technologies on which the competitive position of the enterprise is based: they are mastered by the enterprise and they are incorporated in the main products of the enterprise. Technologies that are purchased outside the enterprise can also be (potentially) very important, but they are not controlled by the enterprise. Changes in purchased technologies may have an unexpected impact on the construction, performance or costs of a product. Sometimes, technological breakthroughs in completely unrelated fields may create opportunities that attract new competitors, who base their strength on this new technology. A well-known example is the use of micro-electronics and plastics in watches, that gave rise to new watch producers and almost destroyed all the mechanical watch manufacturers. An enterprise with in-house R&D activities will usually have more capability to recognize and adopt new developments in its field of business than an enterprise in the same sector that has no internal research capacity. Firms are usually more diversified in their research than in their product range. Nevertheless, the R&D function may be absorbed with the existing technological trajectory and unaware of developments outside, that may be highly relevant to competitive performance. This can happen easily, if the emphasis is mainly on development. Technology management aims to avoid such costly negligence. Efforts may range from a 'technology watch' function to the encouragement of strategic research in technologies that have the potential to destroy the economic value of current competence (as in the case of the watch industry) [5]. In other cases, it is not so much research that is needed, but the creation of know-how and experience at the level of production. That too is then a responsibility for technology management.

** Technology management is concerned with technologies for the primary product/process as well as for the supportive functions in the enterprise.* Especially after the revolution in information and communication technology, competitive performance depends not just on mastery of a core (product or process) technology, but also on the adequate use of (information) technology in support functions like logistics, administration, controlling, and finance. Information technology moves intelligence to the operational levels, allowing for quick feed-back and shorter control-loops. As a con-

5. «Technology watch» is a literal translation of the French expression «veille technologique», which is used regularly in French literature on technology management.

sequence, organizational structures have to be redefined, new information systems installed and related control and management functions redefined.

* *Technology management is concerned with the demands made upon the enterprise by national and international standards and technical regulations.* Standardization is an important and growing area of concern. The need to conform to specific (environmental, health and safety) standards may require firms to invest in new technical competence. On top of that, there is a growing tendency for standards to be formulated in terms of requirements that have to be met at some future point of time. Although the standard-setting body has obviously concluded that these standards are feasible, considerable technological progress may be required this is actually the case. Enterprises can go competing ways in their efforts to achieve the technological preconditions for such standards; in other cases they may find it more attractive to bundle their resources in the necessary 'peri-normative' research.[6]

Technology management, thus, is concerned *with three kinds of technology:* product technologies, process technologies and the technologies used in various supportive functions in the enterprise. Knowledge on these different technologies used to be available in different functionally separate departments in the enterprise: product technology mainly in the R&D departments, process technology mainly in the engineering departments and knowledge on supportive technologies mainly in the central data processing department. With information and communication technology spreading all over the company, organizations are changing their internal structure as well as their relations with their business partners and competitors. Organizational structures based on hierarchy and functional specialization are being replaced by decentralized structures with semi-autonomous business units and teams in which specialists from various disciplines work together (this is sometimes *called process re-engineering* or *integral re-design).*[7] Integration of tasks and continuous communication between different specialists are becoming the rule. Technology and technological knowledge can no longer be located in specific places in the organizational charts. Technology is literally everywhere.

The competitive performance of enterprises and sectors depends to no small degree on their ability to *combine and integrate* these various technologies in an adequate way. Although this could also be argued in the past, it is especially urgent now, because technological change is increasing the options available for each business function, while at the same time interactions and trade-offs between the various business functions are multiplying because of the use of information and communications technologies.

Precisely because the importance of integrating various business functions is steadily increasing, the capability of organizations to do so is lagging behind. As a consequence, enterprises take a fresh look at their operations and try to limit themselves to their core business. This leads to increasing patterns of outsourcing. In an organization that has been made 'lean' by outsourcing, problems of integration and interaction can be managed more easily. The possible drawbacks of greater distance to the outsourced activities are kept under control by intensified relations with the business partners: co-makership, strategic partnerships and other forms of co-operation. The result is the *extended or networked enterprise,* which in many ways is not one enterprise but a group of enterprises behaving or trying to behave as a single actor.

In view of all this, there is a widespread and growing need for conscious management of technological change in every enterprise, regardless of whether it is technology producing or technology using, small or large, high-tech or traditional. Every firm has to view itself as the focal point of a large number of technological developments: every firm has to decide how to make use of these developments, and how to improve upon them. Technology management is concerned with organizing and guiding such decisions.

TECHNOLOGY MANAGEMENT METHODS AND INSTRUMENTS

Business-driven technology management is a relatively new management function that is slowly beginning to define and occupy its place in business organizations. Taking up a mediating and integrating role between several existing management functions (corporate strategy, R&D management, production management, training and organizational development, controlling, and marketing), its basic function is to promote and control technological change inside the enterprise and in the relations between the enterprise and its environment. Technology management is clearly incorporating tasks that sometimes have been carried out by other separate management functions. As such it can make use of several methods and instruments that have been developed in the past for various technology-related activities in the enterprise.

Business-driven technology management involves:

Analysis, evaluation and planning of the technological competence of the enterprise:

- — description and analysis of the technological capabilities of the enterprise in relation to that of its competitors;
- — developing a long-term view of the technology needs of the enterprise in relation to the business strategy;

Optimizing the utilization of the technological competence of the enterprise:

- — promoting and monitoring the utilization or sale of hitherto unused proprietary technology (e.g. patents);
- — monitoring and evaluation of in-house research activities and ensuring effective interfaces between R&D, on the one hand, and finance, strategy, marketing and production, on the other;
- — promoting effective organization in the development and utilization of new technologies throughout the enterprise (multi-disciplinary project teams, simultaneous engineering);
- — promotion of product and process renovation on the basis of research results or other available technological competence.

6. O'Connor (1991); Dankbaar & Van Tulder (1992).

7. The current debate on business process reengineering is in many ways a step back compared to earlier contributions from for instance the so-called sociotechnical school, which has produced excellent and sophisticated tools for the redesign of organisations. See Kuipers & Van Amelsvoort (1990); REDA (1990); Taylor & Felten (1930); Van Eijnatten (1993).

Promoting growth and enrichment of the technological competence of the enterprise:

preparing and monitoring 'make-or-buy decisions' concerning specific technology fields (i.e. choices between in-house research, outsourcing of research, licensing, etc.);

promoting and monitoring technological partnerships with suppliers or customers ('co-makership'), and/or with competitors (in pre-competitive and co-operative research; also research in support of standardisation: pre-normative research as well as conformance testing);

— promoting and monitoring the development of in-house capacities to understand and deal with specific technologies by means of training, acquisition of hard- and software, analysis of competing products, reverse engineering, internal R&D, and hiring of qualified personnel.

Protection and surveillance:

— protection of proprietary knowledge, intellectual property rights, and tacit knowledge available to the enterprise;

— monitoring developments in the technological environment of the enterprise (competing and complementary technologies);

— monitoring activities of relevant standardisation bodies.

For the crucial task of analysis and evaluation, technology management is highly dependent on the expertise of senior personnel and senior managers. It is a well-known fact, however, that these senior people often find it difficult to take a neutral or in any case somewhat distanced view of their enterprise and its technologies. Technology management has the important task of achieving just that: practically forcing the knowledge-carriers of the enterprise to engage in serious and systematic thinking and debate about the technological strengths and weaknesses of the enterprise. To carry out this function, technology management can and often will make use of *outside consultants.* Professional consultants have developed a considerable number of *tools* for the analysis, evaluation and planning of technological competence. Skillful use can produce considerable insights. The quality of the insights, however, often depends more on the expertise that could be tapped than on the method used. The analysis and evaluation of information can be supported by the use of various tools, concepts, categories, but it cannot be done without expert judgment and knowledge of the technologies and markets involved.

Tools for the task of optimizing the utilization of technology can be found in the voluminous literature on the *theory and practice of innovation management.* A considerable part of this literature and related theory is concerned with organizational issues and knowledge on these matters is often available in the departments for personnel and organisation of large organisations, but only seldom used.

Growth and enrichment of technological competence have been the concern of *R&D management.* Although technology management is concerned with a wider range of sources of knowledge, it will be able to use many of the tools of R&D management.

The task of protection and surveillance relies heavily on the collection of information from various data bases. In the field of *technological forecasting* a large number of techniques have been developed to support efforts to look into the future.

It should be noted that many of the tools and concepts used in this field have been created for large, multi-product and multi-divisional enterprises. They require translation to the practices of small and medium-sized enterprises in order to be of use there. One of the major problems of translation is that in small firms several functions are combined in the activities of a single person. Although this is often considered an advantage, because there is no problem of communication, it can also become a disadvantage, if it means that there is no explicit responsibility for the tasks in question. It is often simply assumed that management is keeping an eye on technological developments, but there is no guarantee that this is done in a systematic way; nor that it will not be dropped in view of other, urgent tasks. Of course, the fact that tools and resources are often available for technology management at large enterprises does not guarantee that they will not display the same behaviour as small enterprises. Even large enterprises often have no systematic way of dealing with technological change.

Technology management is clearly a strategic function for every organization. It is strategic both in the sense of being of crucial importance and in the sense of being oriented towards long-term survival. Again, taking a strategic perspective is often considered as a kind of luxury that only large enterprises can afford. It is our contention that this position is increasingly untenable for even the smallest firms. In advanced open economies, the competitive position of enterprises will depend more and more on innovative performance. Competitive positions based purely on low costs are being occupied by competitors from low-wage countries, who are increasingly also able to guarantee quality and punctuality in delivery. Even small firms in traditional sectors, therefore, cannot assume that the past provides a picture of the future; they will have to take care of their own future, develop visions and act accordingly.

Long-term survival in every industry is associated with innovation and the application of new technologies. It should be noted that short-term survival can also be related to innovation, but this is usually of a more incremental kind. Under the influence of Japanese management approaches, continuous incremental improvement has become a key concept in the competitive organization of all kinds of production processes. Continuous improvement (kaizen in Japanese) can make innovation of a more radical kind easier. It often diminishes the technological distance between an old product or process and its successor, because where possible improvements have already been added. It also makes organizations more used to the turmoil and change that accompany innovation. The technology manager will be interested in following continuous improvement activities in order to keep track of the technological competence of the enterprise. The promotion and organization of continuous improvement, however, will usually be a concern of operational management.

TECHNOLOGY MANAGEMENT A QUESTION OF COMPETENCE

In the analysis of the capacity to manage technological change, one can distinguish between three competence.

— technological competence

— entrepreneurial competence
— learning ability

Technological competence is the ability of an enterprise to master the particular technologies that are relevant to its needs. Depending on the more or less cumulative character of change in the relevant area of technology, past research activities will have an important impact on current technological competence, embodied in equipment, in patents as well as in 'human capital' (tacit knowledge). Past levels of achievement, however, can quickly be outdated. Technological competence must be constantly re-created and enhanced if the competitive position of the enterprise is to be maintained, let alone improved.

Technological competence is basically knowledge and know-how. It is a potential that is being created by research, development and engineering activities, by licensing, purchasing and training. As noted above, the presence of this potential is no guarantee that it will be used effectively. Utilization of knowledge requires entrepreneurial competence. *Entrepreneurial competence* is the ability to generate and Implement a strategy for the use and implementation of new technologies, coherently linked to an underlying corporate strategy, taking account of long term trends in the evolution of technology, markets and competition. The emphasis is here on the presence of a vision of the role of technology in the future competitive performance of the enterprise. Obviously, such visions differ in complexity and time horizon, depending on the size and technological basis of the enterprise.[8]

By entrepreneurial action, the enterprise has an impact on its environment. In some cases, the enterprise is even able to create (partly) its own environment: its own markets and its own technological trajectory. But the environment consists of many actors that react and act on their own initiative. Technological change is typically the product of actions by many actors, usually undertaken without much coordination. Technologies are invented and developed in laboratories, incorporated in various products, sold and licenced. The absorption of technologies from outside sources therefore involves interaction, contacts, contracts, cooperation and consultation with other enterprises and other actors in the economy. Enterprises cannot just act, but also have to react and interact. *Learning ability* is the capacity to adapt organisationally and culturally in order to accommodate technological change. Learning ability emphasizes the environment having an impact on the enterprise. Put rather schematically, entrepreneurial competence is the ability to carry out a chosen strategy, whereas learning ability is the capacity to change the strategy and adapt the organization to new requirements. The acquisition of technological competence may be called 'technological learning'; the accomodation to technological change refers to 'organisational learning'.[9]

The insight that technology management is more than the acquisition of technological competence is an important insight. The competitive utilization of technology requires both organizational adaptation and entrepreneurial action. Technology management therefore has an internal and an external dimension: it is concerned with the use of technology in positioning the enterprise on the market, but also with the creation of an appropriate internal environment that is prepared to learn from the signals the enterprise is receiving from its external environment.

In this perspective, technology management is closely intertwined with strategic management, i.e. with the choices made concerning the position of the organisation in relation to its competitors. In a recent comparative study of 'world-class' enterprises in several industries, a Swedish research team found that enterprises with high productivity were situated in market segments with growing demand and good profitability. The researchers emphasize that this is not a coincidence, but that positioning the enterprise on the market and achieving high productivity are in fact two sides of the same coin (Hörnell, 1992). This is, as we would argue, what technology management is all about. *Investment in technology and technological change only makes sense if it is based on a sound business strategy.*

It is important to note that the performance of an enterprise depends not only on its own competence, but also on the competence available in its environment.The point is not just that competence are nurtured by the environment (e.g. by education of future employees and by research carried out at universities), but also that the uses an enterprise make of its competence depend on the challenges made by the environment. Patel and Pavitt (1 991) have shown that the relative technological strength (measured by patenting activities) of firms located in a specific region can be statistically explained by their number and not by their size, Several studies of the Japanese economy have also pointed to the importance of intense competitive pressures on the national market in explaining the competitive performance of Japanese firms. In other words: *competitive pressure can provide a positive contribution to the development of capabilities for technology management in enterprises.*

The three competence can be considered as cumulative. First comes the acquisition of technological competence. If that is in place, entrepreneurial competence is needed to make it effective on the market. Learning ability, finally, is needed to adapt to a changing environment and assure long-term survival. Not all enterprises possess all three competence. Deepending on where they stand, it may require considerable time and effort before they have become «learning organisations». Organisations that do not «learn to learn», however, are bound to die.

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8. The concept of «competence» has become well-known through the influential article by Prahalad & Hamel (1990. It should be noted that our use of the word «competence» is broader than that by Prahalad and Hamel, whose «core competence» refers primarily to technological competence.

9. Dodgson (1991) provides an in-depth case study of the management of technological learnlng in a company. In our approach, learning ability also revolves the capacity to understand movements in the market (which may be related to technological change) and to structure an re-structure the organisatlon of the enterprise to deal with these changes.

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