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Technological management: expanding the perspective of management of technology

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Abstract

This article shows that R&D management, Management of Technology (MOT) and Technological Management (TOM) differ in terms of stakes, stakeholders and scope. Advocates considering technology not only as an asset or a capability but also as a factor that has an impact on almost every management method and practice. Relying on recognized lists of management disciplines, offers an attempt to identify main technology-related issues in each of these fields of management.

It is widely recognized that global competitive strategies are increasingly becoming technology-driven in the context of extremely dynamic, high-velocity, and turbulent environments (Badawy, 1998). Such a context of rapid technological change is obviously extremely risky. As a consequence, managers used to be advised by management of technology academics and practitioners to get a better understanding of the technologies they are implementing and developing and have a clear vision of the role of technology in their corporate strategy. The aim of this paper is to stress that, at the same time, they must also control the impact of technology on marketing, finance and human resources functions of the firm.

From the very beginning, the management of technology (MOT) has been under the strong influence of engineering-based disciplines. The field's structure was inherited from research and development (R&D) management and the mainstream in the literature initially dealt with topics such as project evaluation and selection, R&D organization, technology forecasting, etc. Strong emphasis was put on the management of technological assets. Economists helped to analyze public policy issues and to explore differences in management of technology according to industry, size or country. Nevertheless, the impact of management disciplines remained relatively marginal.

From a rapid survey of previous International Association of Management Of Technology conferences (Khalil, 1990, 1994; Mason *et al.*, 1996), it appears that, progressively, management scholars tried to expand the scope of the field, opening new areas such as technology and human and social issues, technology and business strategy, etc.

In this paper, we will advocate that management of technology would benefit from a stronger influence of management

disciplines such as accounting and control, finance, marketing, human research management, organizational behavior – through a transversal structuring of the field. Such a perspective helps escape from a view which is far too focused on the management of the technology portfolio. Rather than narrowing the scope of the management of technology, this view allows one to consider the impact of technology on each of the traditional management disciplines. Technology becomes more than an idiosyncratic set of resources: it is the common thread of an integrated management perspective.

Towards a transdisciplinary approach to technological management

Since this paper aims to set the scene for management of technology and technological management, we will first review the mainstream in the management of technology and then, using the 3S model – for stakes, stakeholders and scope – we will stress the differences between R&D management, management of technology and technological management.

The establishment's view of management of technology

The management of technology developed in the mid-1980s. This section will quickly present some of the most-quoted definitions. Following the proposal of the National Research Council (1987), the management of technology could be seen as the intersection of two scientific disciplines, previously unconnected, which allowed the merging of technical and managerial competencies (see Figure 1). The idea was to export existing management methods to the management of technological assets.

The Task Force on Management of Technology, supported by the National Research Council (NRC) in the United States, decided that "The management of technology links

An early version of this paper was presented at the 1999 IAMOT Conference, Cairo, Egypt.

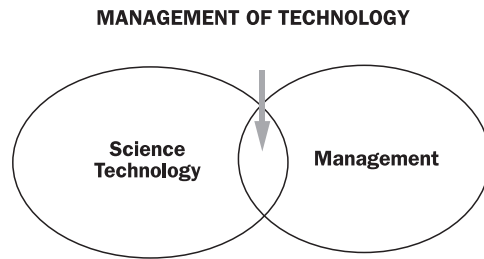
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Figure 1
Management of technology as a merger



engineering, science and management disciplines to plan, develop, and implement technological capabilities to shape and accomplish the strategic and operational objectives of an organization". According to the authors, the unit of analysis is clearly the technological capabilities of the firm – in other words, its portfolio of technologies. As a consequence of this definition, the *raison d'être* of MOT is to set up the congruence between the technology portfolio and the organization's objectives and targets.

In his paper presented at the Second International Conference on Management of Technology, in Miami, Bayraktar (1990) gave the following broad definition: "a rational and systematic view of responding to technological opportunities and innovations, and dealing with their consequences". One will easily recognize that the latter (the consequences) have been neglected. To justify why the management of technology became the focus of widespread attention (task forces, workshops, conferences and symposia, specific courses and degrees, a Presidential Commission in the USA, etc.), he referred mainly to the unprecedented scope and speed of technological innovations and breakthroughs and to the increasing human and financial resources dedicated to R&D.

According to Bayraktar (1990), the National Research Council's task force adopted a very narrow view of technology which was seen as the tools, techniques and procedures used to accomplish industrial purposes. His own definition also reduced the scope of management of technology to the "decision problems, at all levels, related to the creation and utilization of technological assets and capabilities". It covers:

- creating new technologies and using effectively and efficiently existing technologies;
- responding to and coping with the impacts and effects of technological change on individuals, organizations, society and nature;

- developing methods, techniques and procedures for dealing with technological issues and problems.

There was clearly no interest in dealing with the impacts of technology on managerial practices, methods and finally management sciences.

Later, Dankbaar (1993) suggested encompassing in technology management "all management activities associated with the procurement of technology, with research, development, adaptation and accommodation of technologies in the enterprise, and the exploitation of technologies for the production of goods and services. Dankbaar is using "technology management and management of technological change as synonymous expressions".

These definitions are broadly accepted by the scientific community which recognizes itself through the International Association for the Management Of Technology (IAMOT). Most textbooks[1] and research works published in specialized journals such as the *International Journal of Technology Management (IJTM)*, the *International Journal of Innovation Management (IJIM)*, *Technology Analysis and Strategic Management*, *Technovation*, etc., or presented in international conferences such as the International Association for the Management of Technology (IAMOT), International Forum on Technology Management (IFTM), Portland International Conference on Management of Engineering and Technology (PICMET), etc. have adopted the point of view of a discipline looking at the management of technological assets. These definitions have also been adopted by several leading institutions and public bodies such as the National Research Council in the USA, and the Commission of the European Communities (Programme SAST-MONITOR). This paper suggests reserving the acronym MOT for such a conventional approach.

More recently, Badawy (1998) suggested that the management of technology is the practice of integrating technology strategy with business strategy, contributing to enlarging the conventional definition when stating that such integration requires the deliberate coordination of R&D, manufacturing and other service functions. While recognizing that the management of technology has a fragmented research base and is yet an evolving discipline, the author is still reducing the target of technology management education to technologists.

Towards a transversal vision

To define what we call an overall transversal vision, a clear distinction should be made between three areas or sub-disciplines, i.e. R&D management, management of technology, and technological management. Obviously, they are complementary and closely related to each other.

Historical evolution

Figure 2 suggests that, over the years, the scope of the field has expanded to encompass an increasing range of managerial issues and cover more and more topics. Such evolution is linked to major shifts in the perspective of management. The move from R&D management to management of technology could be related to the following changes:

- A change in the understanding of the source of technology and therefore of technological opportunities. In the 1960s and 1970s, in-house R&D was considered the main source of technological innovation (Rousset *et al.*, 1991). In the mid-1980s, following hundreds of papers and books related to the economics of innovation and technological change, many sources were identified for innovation: alliance modes (R&D joint ventures, consortia, license swaps, etc.), subcontracted R&D, acquisitions, etc. In the management literature, the concept of technology portfolio emerged (Pappas, 1984).
- A change in the status from operational to a more strategic positioning: at the time of R&D management, top management delegated technical choices within the R&D department (Pavitt, 1990). The only involvement of top management was to set a target of R&D effort as a percentage of the turnover. It was the responsibility of R&D managers to optimize this resource

allocation. The management of technology gained strategic content which justified growing involvement of top management in technical decisions.

The continuing move towards technological management is associated with the following reasons:

- An increasing acceptance that technology is not an issue which should be confined to researchers and engineers involved in creating and optimizing a portfolio but is a key variable that has an impact on everyone within the organization.
- An increasing recognition that management efficiency, and obviously business success, is associated with breaking down barriers and spanning bridges between disciplines and functions, leading to a transversal and integrated vision.

The 3S differentiation

How do R&D management, the management of technology and technological management differ? Their stakes, stakeholders and scope – we suggest to name it the 3S model – are different enough to justify such distinction.

Stakes

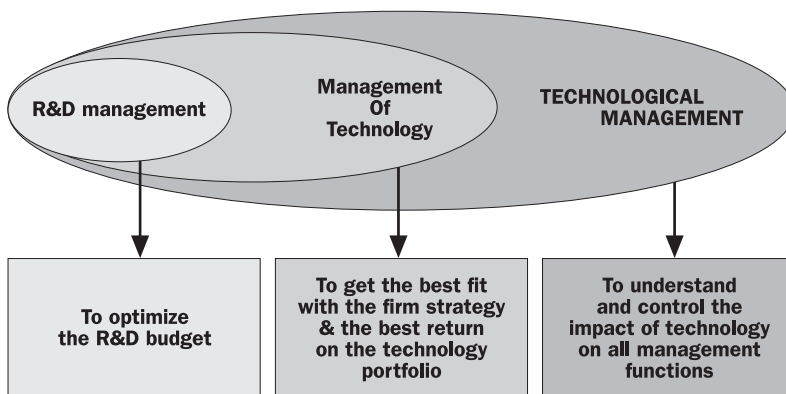
First, R&D management, the management of technology and technological management have different *raison d'être* or rationales associated with differentiated objectives.

It is now widely recognized that R&D activities, programs and projects should be properly managed since luck or chance are rarely the real source of innovation. A structured management with operational procedures and formal methods is needed in order to optimize the R&D budget. Since R&D became a crucial function as the source for new technologies (new products as well as new processes), the allocation of financial, human and organizational resources to the R&D department or unit became a key management issue. In such an approach, the link between R&D management and corporate strategy does not necessarily need to be strong and explicit.

Since technology was perceived as part of a portfolio and managed by several functions within the business unit – R&D, manufacturing and information systems, at least – and since engineers and managers understood that they should work together, the need for a more comprehensive approach emerged, giving birth to the management of technology. The rationale for the latter is to reinforce the business's technological edge and to find new competitive advantages from expanding, developing, renewing, and/or rejuvenating its technological competencies and resources. Its objective is to maximize

Figure 2

The relationship between R&D management, MOT and technological management



the return on any dollar invested in its technology portfolio at all levels of the organization and all stages of the innovation process including creation and use of technology.

Technological management's *raison d'être* is using technology to leverage all functions within the company. It perceives technology as an impacting variable and a major resource for all management functions as a producer, a customer or a user. In other words, it assumes that any management function should take technology as an input shaping both its strategic vision and its operational procedures and methods. The objective is then to make technology strictly coherent and compatible with the short- and long-term activities of all departments or business units.

Stakeholders

R&D management, the management of technology and technological management also differ in terms of the type of firm, the people involved in decision making and those involved in their day-to-day practice.

R&D managers and staff are primarily concerned with R&D management even if some marketing people may be interested in taking part in R&D program management. But most of the tasks should be carried out by R&D people, especially the optimization of the R&D budget as previously explained. All medium and high-tech companies running their own internal R&D laboratories are targeted since firms without R&D departments do not really care about R&D management.

The management of a technology portfolio clearly requires a specific profile for decision making since it covers several diversified tasks and functions within the business and with external partners. It involves all engineers, technicians, and researchers in the R&D unit and manufacturing activities. Again, this is relevant to most medium and high-tech companies.

Due to its definition, technological management is relevant to anyone using, consuming or creating technology within the organization. The top managers at all functional levels are the real decision makers, and any organization – high, medium or low-tech – is concerned. Even firms without R&D departments should pay attention to technology[2].

Scope

Finally R&D management, the management of technology and technological management do not have the same concerns and units of analysis and do not address the same

managerial issues. They do not have the same perspective.

The scope of R&D management is rather limited. R&D projects and programs are the unit of analysis. The main issues for R&D management are definition, evaluation and selection of R&D projects, R&D organization, R&D forecasting and scanning.

The management of technology deals with technology portfolio, i.e. the whole range of technological assets disseminated within the organization. Its scope is therefore broader than R&D management and it has to deal with numerous issues such as technology forecasting, scanning, creation and development, acquisition, exploitation, dissemination, commercialization, transfer, implementation and withdrawal.

As a transversal and global discipline, technological management will tackle management functions as units of analysis. In other words (see Figure 3), TM deals with marketing and technology, finance and technology, human resource management and technology, strategy and technology, etc. It looks at technology as an input.

Figure 3 shows that every management function deals with a specific set of resources: human resource management (HRM) deals with people, organizational behaviour (OB) with organizational resources, production and organization management (POM) with physical assets, marketing with market channels and brand reputation. In the same vein, management of technology deals with technological resources. But, technological management does not deal with a specific set of resources: its role is to capture and control the impact of technology on every management field. In this framework, technology is the impact variable as countries and cultures are the variables that are shaping international management. The figure emphasizes the transversalism of some management disciplines such as technological management and international management. Such transversality pinpoints the co-evolution with traditional approaches.

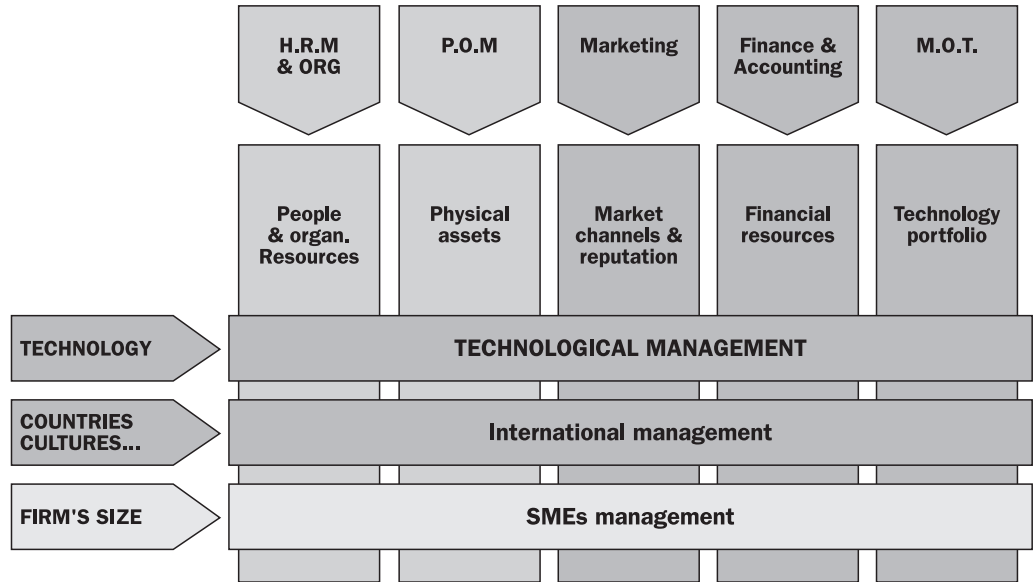
Towards a typology

We will first examine the traditional structure of management disciplines. Then, we will use this framework to highlight issues covered by technological management.

The conventional classification of management disciplines

Management education and training as well as the research associated with management

Figure 3
 Technological management: a transversal vision



Adapted from: J. Barrant, D. Jolly (1995)

have progressively developed in industrial countries since the 1950s. Year after year, the field has structured itself into different sub-fields. The present paragraph intends to cast light on the following questions: How is the field of management structured nowadays? Is there any shared overall framework? What are the main sub-fields – whether they be called divisions, disciplines, interest groups or chapters?

In order to provide an answer to these questions, using the Internet, we had a look at the academic departments of well-known business schools (such as Harvard Business School, Insead in France, London Business School, etc.), the divisions or chapters of several academic management associations (such as the Academy of Management, ASAC, etc.), the headings of different case clearing houses (Harvard Business School, ECCH, Western Ontario, etc.), and finally the well-accepted keywords of a library thesaurus.

This investigation led us to distinguish three types of sub-fields:

Major divisions

Here are the genuine and traditional management disciplines. They are usually organized under seven headings:

- 1 Accounting and control are probably amongst the oldest management disciplines and are very technical.
- 2 Finance is nowadays seen as an autonomous discipline with its own associations

and conferences. It has very strong economic roots.

- 3 Production and operation management (POM) is, along with the two previous disciplines, one of the oldest fields in management.
- 4 Marketing quickly gained its credentials. This discipline has its own numerous sub-fields.
- 5 Human resource management (HRM) is usually considered as the soft side of management.
- 6 Organizational behavior has developed in parallel with human resource management.
- 7 Management of information systems (MIS) is probably the latest to gain recognition as an autonomous discipline.

Transversal areas

These are fields that did not emerge as extensions of the previous list but rather took on a different perspective. International business is probably the best known example of such a different angle. This field addresses international issues for all management disciplines. The idea is to look at the specific HRM issues raised by the management of expatriates, local people and cultural differences. The list of transversal areas is not finite. Typical examples include: policy, strategy, general management, entrepreneurship, Asian business etc. Innovation management can also be included under this heading.

Related areas

These are, in fact, sub-fields of disciplines different from management. For example, management sciences evolved from decision sciences. In the same vein, business history is a chapter of history studies. Related areas share the same characteristics as what we call transversal areas. It is not possible to draw up an exhaustive list of the domains. Nevertheless, apart from the previous examples, we can also cite the following: tourism and hospitality management, health care administration, management education, women in management.

Key issues

Since they could lead to the revision and reconstruction of existing paradigms, the many impacts of technology on management activities and functions are opening a large research spectrum. Such a transversal vision of technological management suggests that a specific perspective is needed when dealing simultaneously with technology and any other management issue. We will now propose some of the issues which could be addressed by such a transversal vision. This section relies heavily on a previous attempt to identify issues related to the impact of technology on accounting, finance, human resource management and organizational behavior (Jolly and Alii, 1996). The purpose of this paper is not to set up a comprehensive list of key issues but simply to illustrate our point of view with a few examples.

Accounting and auditing

When producing or using high technology, a business unit is trying to gain some competitive advantage through specific assets and key know-how. Technological management should address methodological as well as practical evaluation and reporting issues.

Regarding accounting techniques and methods, TOM might be concerned with defining accounting principles which should be developed in order to take into account intellectual capital, immaterial assets and resources, knowledge and know-how; measuring internal and external value which should be given to such items; gathering and analyzing data which are relevant and should be emphasized when carrying out a market study in high-tech industries, etc.

Practical managerial issues are mainly associated with the impact of information technologies on accounting practices and organization, auditing procedures and tools (Godener and Gonthier, 1998). Some other

questions are related to the adoption of expert systems and sophisticated software.

Finance

The impact of technology on finance is apparently a neglected domain. Technological management should address issues dealing with financial choices, financial value, financial sourcing, shareholder redistribution, and indeed the structure of shareholding, etc. Two main streams of research can be distinguished:

- 1 Event impact studies on value. Does technology-related information disclosure have an impact on the company market value, be it positive or negative? For example, what is the impact on the firm's market value of the announcement of a major discovery, of a new patent, of the successful implementation of a process innovation?
- 2 Financial policy. Should the financial policy of a high-tech company differ from that of a low-tech company? For example, should the equity-debt ratio or the dividend policy be high-tech specific (Bah and Dumontier, 1998)? If so, we need to develop new financing techniques, portfolio structure, etc.

Human resources and organizational behaviour

This is a more highly-developed domain with major research work being carried out on issues such as creativity enhancement, technical staff management (selection, hiring, assessment, etc.). But further research is deeply needed in many key areas which could be grouped into three main domains:

- 1 *Individual competence and training*: key issues are, for instance, acquiring, developing and sustaining technical competences in a changing environment, forecasting new competences required by new technologies, life-long training costs etc.
- 2 *Individual performances*: crucial questions are, for example, increasing team efficiency, increasing or modifying motivation, individual positioning and behavior within a high-tech organization, modeling tasks and job flexibility, etc.
- 3 *Group behavior*: important areas are, for instance, modeling internal management of technology perception and image, technology and corporate culture, etc.

The impact of technology on the organization is well-known but is perceived everywhere as a challenge and a key to survival. Key issues are, for instance: technology and creativity; technology and interpersonal and

inter-functional exchanges; selection and design of information and diffusion paths; ways to have access to and to use information; technology and organizational learning, etc.

Production and operation management (POM) and management of information systems

Naturally, these functions have been investigated by MOT from the very beginning since they are activities which are technical by definition. In general, the impact of information technologies (IT) on POM is the most congruent with technological management. Some examples of issues for which further research is deeply needed are:

- impact of IT on flexible manufacturing systems and, in particular, the impact of the Internet;
- Impact of IT on product development, e.g. rapid prototyping, CAD/CAM implementation, etc.; and
- impact of IT on logistics and procurement.

Obviously, technology and the management of information systems (MIS) have very close links. Crucial issues are, for example:

- impact of the ever-increasing power of information systems within the organization;
- role of MIS in reshaping overall company structure.

Marketing

The introduction of technological considerations into the discipline of marketing implies a complete turnaround in the way we think about marketing. Whereas marketing is frequently associated with market-pull approaches, technology is much more associated with technology-push innovations. Marketing is fundamentally oriented downward, i.e. towards the demand. Its aim is to acquire a better understanding of the consumer. As a matter of fact, the discipline developed originally for consumer goods. Its ultimate role is to help differentiate between comparable end products thanks to positioning, advertising, promotion, etc. Conversely, technology is much more associated with supply side rather than demand side. Technology is usually considered a means for enriching supply. Nevertheless, introducing the technology variable on the marketing scene does not reduce the importance of marketing. It might even be the contrary (Bouvard, 1998). The task of marketing moves backward in the process. Its role becomes crucial in identifying new applications, new functions, new clients of the company technology portfolio. At least four domains could be covered:

- 1 use of technology to help sell or differentiate a product, a service, etc.;
- 2 marketing of high-tech products (pricing, promotion, distribution, etc.);
- 3 impact of new information technologies on the way market research is conducted; and
- 4 impact of new information technologies on the way products and services are sold and distributed (see the example of electronic commerce (Jolly, 1998)).

Conclusions and implications

This paper presented a transversal vision of the management of technology-related issues which integrate the impact of technology on management functions with the management of technology.

Technological management requires competencies in a broad spectrum of functional areas from R&D to marketing, finance and all other traditional managerial activities. It does require an interdisciplinary vision and therefore a multidisciplinary background.

We would like to emphasize four main implications for our paper:

- 1 While the mission of traditional management disciplines is to deal with an array of specific resources, technological management does not have to allocate resources. It rather aims at capturing and mastering the shaping effects of technological variables on businesses.
- 2 Technology is not restricted to the field of technical functions. Technological management is targeting a much broader view. It deals with stakeholders who so far have not employed and are even scared of technological variables, such as accountants and finance experts.
- 3 A firm does not necessarily need an R&D department to have to manage technical issues. Therefore, technological management is not only a high-tech business fashion but it also concerns low-tech businesses where the diffusion of new technologies might have a significant impact.
- 4 When adopting such a transversal approach to technological management, we are stating that managers as well as practitioners and academia should be educated and trained in such a way that they should be able to identify, analyze, understand and evaluate the co-evolution of technology and management. They should also be able to fully integrate technological change in their decision-making process at both strategic and operational levels. Technological

management excludes monocultural and extremely specialized education and in particular in both engineering and management schools. It calls for an integrative and systemic approach in graduate and post-graduate education with enough technology-oriented disciplines in business schools and enough managerial education in engineering schools. It might require the co-development of programs by engineering schools and business schools.

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Application questions

- 1 How have you been educated and trained to understand the impact of technology on management in your organization?
- 2 Following the authors' arguments, should there be any such person as an information professional?

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