

Technological Management: A Tentative Research Agenda

Jean-Jacques Chanaron,

CNRS, Professor at Groupe ESC Grenoble

chanaron@esc-grenoble.fr

Dominique Jolly and Klas Soderquist,

Professors at Groupe ESC Grenoble

jolly@esc-grenoble.fr

soderquist@esc-grenoble.fr

Abstract

This paper develops our vision of Technological Management through the development of a tentative research agenda. Technology is not only considered as an asset or a capability, but also as an integral factor that has an impact on all management disciplines. Through the existing literature, business schools' research programs and the contribution of key academics we identify central topics for further research on the interface between technology and the following management disciplines: finance, accounting/control, human resource management/organisational behaviour, marketing, and operations management.

Keywords: management of technology, technological management, impact of technology on management, management of technology intensive firms, systems analysis.

Introduction

This paper builds on previous research focusing on expanding the traditional approach regarding technology -Management of Technology (MOT)- towards a transversal and comprehensive vision of Technological Management (ToM) (Chanaron & Jolly, 1999).

Technological management is defined as the integration and the employment of technology in order to leverage all functions within the company. It perceives technology as a major resource and an impacting variable for all management functions whether they are "producers", "customers" or "users" of technology. In other words, technological management assumes that any management function will make use of technology on the one hand, and should consider technology as an input shaping both its strategic vision and its operational procedures and methods on the other. The objective is then to make technology strictly coherent and compatible with the short and long-term activities of all departments or business units, in order to leverage performance in relation to fixed business targets. The stakeholders of ToM are all the managers and staff using, consuming or creating technology within the organisation. The top managers at all functional levels are the real decision-makers concerning how technology will be used and how it will be allowed to shape strategy, structure and operations. Moreover, any organisation -high, medium or low-tech- is concerned. As a transversal and global discipline, technological management has a specific target: to tackle management functions as units of analysis, and to study the use and the impact of technology on these management functions.

A Systemic Philosophy

The approach of technological management is truly “systemic”, derived from a vision of a phenomenon, in this case technology, at the core of all dimensions of management science and practice. According to systems thinking (Open University Systems Group, 1988), this means that technology is an essential element of any business organisation system, and that there is a set of active links between technology and all the other elements of the system: research and development; finance; accounting/control; organisation and human resource management; marketing; operations; information systems; and law. In other words, technology is impacted by and has an impact on those functions. The present paper is limited to the operative functions of a company, as illustrated in figure 1. Moreover, the relationship between R&D and technology is not dealt with. It will be developed in a forthcoming paper.

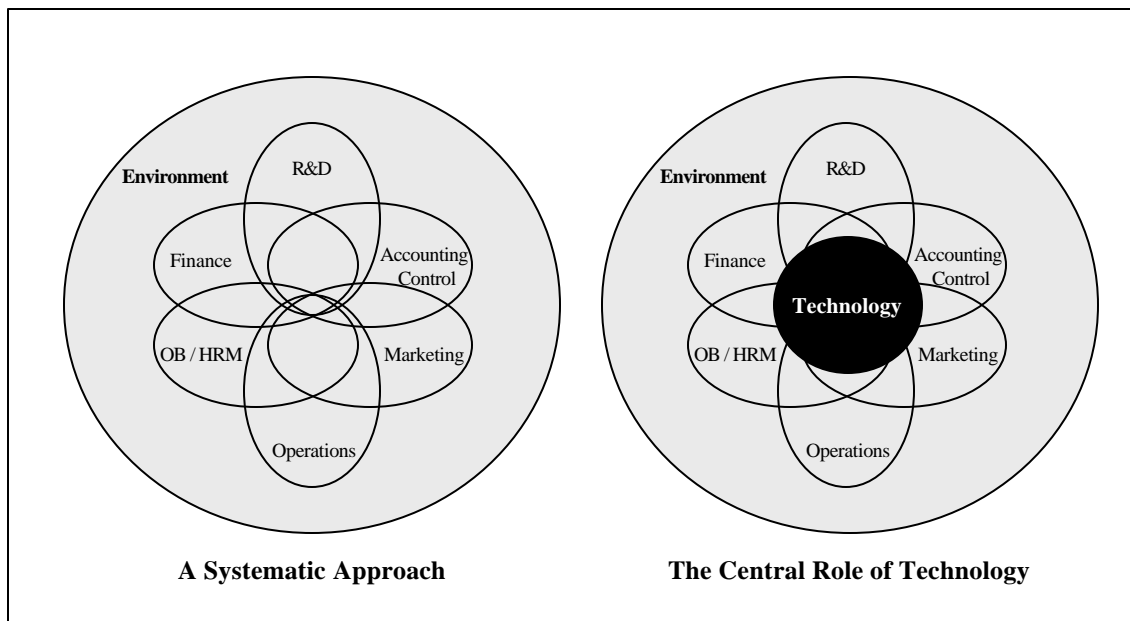


Figure 1. A systemic approach to technology and the operative functions of a firm.

The traditional approach supposes that each element is performed relatively independently. A systemic approach considers that since they are obviously interdependent, they deserve an integrated vision using compatible and coherent managerial tools and methods. This approach must take into account both the impact of technology on managerial functions, and therefore their specific techniques, and the management of the generation of technology within each discipline.

Two Main Research Tracks

When dealing with technology and management in finance, accounting/control, human resource management and organisational behaviour, marketing, and operations management two common paths emerge for further research:

Managing technology as an activity from the point of view of the technology producer, predominantly technology intensive firms. The central hypothesis of this path is that there is no management practice or theory that can escape from contingent factors, notably the influence of the industrial sectors. The idea is that when a sector exhibits a high level of technical content and the firms in this business are technology-based organisations,

i.e. employ a large proportion of technical professionals, then, management disciplines display specific characteristics;

Managing technology as a resource from the point of view of the technology deployment, independent of the technological intensity of the organisation. Whatever the technological intensity of one given firm, the introduction of new technologies is frequently accompanied by significant changes.

In this paper we will show that these two paths exist for each of the management disciplines studied (c.f. figure 1, with the exception of R&D).

Technology and Finance

Within academia, finance used to be a management discipline that was scarcely connected to technology. Not only because a strong tradition had designed very strict limits to its scope, but also because technology and innovation were not yet core concepts in theoretical or applied research. However, in the real world, finance clearly plays an increasing role in technology-based activities, such as technology intensive entrepreneurial start-ups¹.

According to Jobart & Vailhen (1999), finance, while being a transversal discipline in management science, is usually dedicated to two main research areas: financial market analysis and corporate finance. However, when scanning the literature and surveying the current programmes at key research centres (as found on their web sites), it could be seen that two more research topics should be added: corporate governance and financial institutions. Nevertheless, researchers in finance, accounting and control are paying a growing attention to issues and topics that fit well with our vision of technological management and they are contributing to the establishment of a research agenda. Such research programs are concerned with two key research paths: Financing technology as an activity; and Using technology as a resource in finance.

Financing Technology as an Activity

Three main research domains can be identified within this path:

Public finance and technology: This domain looks at such issues as: public, financial and fiscal incentive schemes; R&D and innovation; the financing of R&D-business interfaces.

Corporate finance for technology intensive industries: This topic, which is the most popular amongst researchers, includes themes such as: financing start-ups and entrepreneurs; seed investment; venture capital; transmitting technology intensive family businesses; stock options in technology intensive firms; financing innovation and R&D (Bah, 1998); micro-loans; financing mergers and acquisitions in technology intensive industries.

Financial market analysis in technology intensive industries: This domain deals with subjects such as: Initial Public Offer (IPO) of technology intensive businesses; risk evaluation; impact

¹ A good example of this importance of finance is shown by the outstanding market value of newly emerging internet or biotech companies.

of a technology-related announcement, such as a discovery, on the firm's market value; evaluating technology intensive family businesses.

At a purely theoretical level, the research agenda in finance is related to risk management, agency theory and the valuation of immaterial assets. There is an impressive body of up-to-date literature on financing technology intensive businesses, presented in textbooks, articles and conference papers dealing with corporate finance for SMEs. Such literature is mainly based on applied research, leading to strategy recommendation for both borrowing and financing institutions. Predominantly, research programs belong to financial engineering.

Using Technology as a Resource in Finance

Particularly in relation to new information and communication technologies, two main topics are emerging:

Innovating in finance: This issue includes themes such as: credit cards and SMEs; IT in finance; smart finance; decision technologies for computational finance.

Impact of ICT (information and communication technologies) on financial institutions: This theme is largely connected to issues in HRM and organisation, dealing with the impacts on jobs, competencies, organisational structure, and so on.

There is obviously a need for further research regarding the diffusion of ICT in finance.

Technology and Accounting, Control

As far as accounting and control are concerned, it is yet more evident that technology is not a key research area. It must be emphasised that these two areas are closer to a set of practical tools than to true scientific disciplines.

Apart from traditional investigations into accounting and auditing techniques, the most popular topics within current research programs - gleaned from interviews and the most relevant business schools' web sites - are the following:

- The nature and needs of financial reporting and communication in a national and international context;
- The creative and manipulative use of financial communication;
- The role of auditing and financial information in the corporate governance process;
- Social and environmental accounting.

An emerging body of literature is also dealing with issues that link technology with accounting and control, thereby providing some guidelines for a research agenda:

Accounting and auditing in technology intensive enterprises: Once again this is the most developed research path as far as technology and accounting/control are concerned. Research issues include: auditing techniques and cost accounting in technology intensive firms; accounting and auditing for hybrid, virtual or network organisations; impacts of accounting information on decision-makers and markets; development of suitable measures of performance in technology intensive industries; development of new accounting techniques in a context of dematerialization; relationships between auditing information and the

governance structure; project appraisal: start up, closure, economic benefits; corporate valuation under uncertainty; technology transfer evaluation and measurement.

Using ICT in accounting and control: This domain looks at research themes such as: impacts of ICT in accountancy and control (Godener & Gonthier, 1998); developing new accounting and auditing software; accounting and sustainability; decision technologies, expert systems based on accounting information; intelligent systems for business diagnosis; modelling accounting information; managing the interface between accounting and strategic planning.

To sum up, there are two predominant directions for further research in the interface between technology and accounting/control:

Investigating new models of management through accounting and auditing in technology-based industries;

Developing new accounting and auditing methods and practices using new information technologies in relation to technology intensive enterprises. For example, the implementation of Enterprise Resource Planning Systems such as SAP or BAAN is already one of the most popular applied research topics and will surely be part of a common research agenda between accounting and the auditing and management of information systems.

Technology and People

Most of the core textbooks used in Human Resources Management (HRM) and Organisational Behaviour (OB) share a common view about the content of these disciplines. Generally speaking, OB adopts an overall framework dealing with the management of individuals, groups, organisations, processes and dynamic environments (Schermerhorn et al, 1991), while HRM focuses on the specific issues within this framework such as: hiring and recruitment; remuneration; career management; management of competencies and training; management of hierarchical levels; internal communication; and evaluation of staff. In this framework, the issue of people and technology is not a new one (cf. e.g. Allen, 1977; Kleingarten & Anderson, 1987) but it is currently undergoing significant renewal with the emergence of pervasive new technologies, especially in the field of ICT (Ettighoffer & Blanc, 1998; Townsend et al, 1998).

HRM and OB in Technology Intensive Firms

In these firms, HRM and OB have to deal with scientists, researchers, engineers, technicians and other technologists (Katz, 1997). The issue is to identify the critical parameters in HRM and OB that technology intensive companies need to customise (Hinds & Kiesler, 1995; Barrette & Simeus, 1997; Picq, 1999; Jolly & Roche, 1999). Each of the critical parameters could be assimilated into the framework identified in the previous paragraph.

Two dominant areas for HRM and OB in technology intensive firms can be distinguished. A first one relates to the management of advanced knowledge, in other words the acquisition, building, maintaining, development, and sharing of the specific knowledge that is the very foundation of every technology intensive firm. A second area covers any action that deals with rapid change and uncertainty, the norm in technology intensive environments.

Managing advanced knowledge: Examples of research themes are: the implementation of specific recruitment practices; implementation of individual career paths; motivation of R&D teams and engineers; the role of training for knowledge accrual in technology intensive environments; forecasting new competencies needed by new technologies; enhancing creativity and developing human resource capabilities; communication patterns and a communication culture to support innovation.

Coping with rapid change and uncertainty: Examples of the research themes here are: the key success factors related to people in a technology development project; measurement of R&D effectiveness; dealing with high turn-over of staff; evaluating the staff in rapidly changing technological markets; and transformation of advanced engineering into products.

The Use of Technology for OB and HRM

Research in this area deals essentially with the choice of new ICT-based tools for managing people (Haines & Petit, 1997). HRM managers are looking for tools that can help them to better understand those issues on which they have to take decisions. Two sub-paths can be distinguished. The first deals with managing people with the help of technological tools, the second with the impact of technology on the performance of people at work.

Managing people with the help of technological tools: In this area research is dealing with the use of tools such as ERP systems (Enterprise Resource Planning), competence trees, and performance monitoring systems. These tools give the impression of managing people more rationally, while at the same time a mechanistic way of looking at the complex problem of qualifications, competencies, and career development can emerge. The effects on HRM and OB are here to be explored.

The impact of technology on the performance of people at work: New technologies may have a tremendous impact on job environment, job design and content, as well as on the attitudes towards work and job satisfaction. A well-established body of literature deals with such impacts of technology on people and organisations - for example, the effects of mechanisation or automation (see e.g. Bailey, 1993). It shows how important it is to pay attention to human issues when it comes to the implementation of a new technology. In line with this philosophy, current research deals with impact of ICT, in particular office automation (Hinds & Kiesler, 1995; Lind & Zmud, 1995). Research shows that the management of organisations and human resources needs to adopt a proactive, rather than a reactive, approach to these issues (Jacob & Ducharme, 1995; Ettighoffer & Blanc, 1998). Key research themes include: people's reaction to the introduction of new information technologies; impacts of these new technologies on jobs and competencies; policies to facilitate the implementation; impact of IT on communications networks and knowledge management; implementation of an Intranet and its impact on people's behaviour; organisational issues regarding the introduction of new technologies; managing the ever-increasing flow of information; consequences of the increased use of telecommunications networks on individual and group productivity (and, ultimately, on business performance).

Technology and Marketing

Since the dawn of marketing, the discipline has split into two distinct sub-fields. The first is commonly known as market research, involving the study of consumer behaviour in

its environment through the use of tools such as market studies, segmentation, market forecasts, ... The second is the marketing-mix and its implementation which deals with the famous 4 Ps: Product, Price, Place and Promotion.

The introduction of technological considerations into the discipline of marketing implies a complete turnaround in the way we think about this subject. Whereas marketing is frequently associated with market-pull approaches, technology is rather associated to technology-push innovations. Marketing is fundamentally orientated downwards, i.e. towards demand. Its aim is to acquire a better understanding of the consumer and, as a matter of fact, the discipline was originally developed for consumer goods. Marketing's ultimate role is to help differentiate between comparable end products through positioning, advertising, promotion, etc. Technology, conversely, is associated with the supply side rather than that of demand; technology is usually considered as a means for enriching supply. Nevertheless, introducing the technology variable on the marketing scene does not reduce the importance of marketing, rather it implies the contrary (Schanklin & Ryans, 1987). Marketing management and the marketing activities are moving upstream in the process of realising products and services. Their role becomes crucial for identifying new applications, new functions, and new customers for the company's technology portfolio.

Marketing in Technology Intensive Companies

Clearly, the technological content of a product has a serious impact on marketing practices and theories (c.f. e.g. Millier, 1989; Gaillard, 1997). Related topics are: developing a marketing culture in technology intensive environments; assisting the R&D / marketing interface; meeting customers' expectations in technology intensive environments; coping with the rapidly changing segmentation and short life cycles that are associated with technology intensive businesses; dealing simultaneously with market and technological uncertainty; contribution of market research to uncertain and ambiguous demands; impact of marketing on the diffusion of technology intensive products; pricing an entirely new technology intensive product or service; specific features of the launch of a technology intensive product; elements to take into consideration in order to promote, sell and distribute complex products.

The Use of Technology for Marketing

The study of consumer behaviour using new information technologies is a rapidly expanding field (Jolly, 1998). Among the challenging research topics we find: the impact of e-commerce on the traditional sales force; the World- Wide Web as a real threat for traditional commercial networks; the future of traditional distribution networks; and using technology for enriching the firm's products and services, and for speeding up delivery.

Technology and Operations Management

The essence of operations is to transform or convert a set of inputs, such as materials, labour and equipment, into one or more outputs: products or services or a combination of both (Martinich, 1997). Operations management studies and practices the process of *planning, designing, and operating* production or *servuction* systems (hereafter called production systems) to achieve an organisation's goals (Martinich, 1997; Stevenson, 1996).

Operations Management in Technology-Intensive Firms

The effects of technological uncertainty, rapidly changing and growing markets, and the need for state-of-the-art scientific and technological knowledge in technology intensive firms affect operations management in many different ways. Two areas seem to attract specific interest; the intensive use of outsourcing, and the interplay between product and process technology.

Outsourcing: Outsourcing is a strategic topic. In some of their PC ranges, companies like Hewlett-Packard outsource 100% of their manufacturing and only carry out final assembly and testing. In the automotive industry, a 70-80% outsourcing rate is an objective. Central to this area are: the specific drivers for outsourcing in technology-intensive firms; the consequences of intensive outsourcing in terms of maintaining and developing core competencies, managing knowledge, promoting innovation, managing supplier dependency (in both senses), and managing risk and confidentiality; the effect on materials management and final product quality where intensive outsourcing is a leverage for innovation and technology synergy.

The interplay between product and process technology: This area of research comes close to the management of technological resources. In the case of many innovative products, both the idea and the product technology exist, but the process technology necessary for realising the innovation is not ready. This was for example the case with the C-Pen, the Swedish text scanner in a ballpoint pen format. Conversely, product innovation might be hampered if there is a lack of knowledge of new process technology on the part of design engineers, or if design is the dominating discipline, relegating process engineering to a second level of priority (Bowen et al, 1994). Some important research issues related to these problems are: bridging the gap between R&D and process engineering in technology intensive development projects; ensuring integrated product and process technology scanning; dissemination of process technology information in R&D and Advanced Engineering; conducting benchmarking studies on the application of new process technology to different functional problems; dealing with barriers to effective process development in product-driven firms; managing the advanced knowledge embedded in production processes.

The Use of Technology in Operations Management

Operations management is closely related to several decisive factors for a company's competitive strategy, for example productivity, quality, cost, lead-time, and flexibility. In today's global environment these factors are priorities in any industrial or service firm, and the continuous search for improved performance often utilises technology in different forms. Two fields can be identified as being of particular interest: The introduction of new technology in existing production processes, a topic that is related to the *design* of production systems; The increasing use of information technology in the *operation* of production systems.

The introduction of new technology in existing production processes: Over the last 10-15 years this field has undergone a transformation from research focused on the *machine* - flexible manufacturing systems and computer-aided manufacturing (c.f. e.g. Jaikumar, 1986) - to research focused on the *human being*, i.e. the interface between men and machine, the optimal level of automated and manual work, and the related processes of competence development and job satisfaction (c.f. e.g. Charue & Midler, 1994). Some of the central

research themes are: rigidities that impede the implementation of new technology in an existing production process; strategic, tactical, and operational imperatives that should be taken into consideration when new technology is implemented; establishing the optimal level of automation and computer integration in different manufacturing settings; designing interfaces between men and machines for optimal productivity and ergonomics; impact of new production technology on competitive performance and strength; dealing with supplier dependency where the technology is not internally mastered; creation of true differentiation where new technology can be purchased off-the-shelf.

Use of information technology in the operation of production systems: The current trend in materials management (flow, inventory...) is to take an integrative approach to operations over the entire supply chain, from raw materials to the final customer. In fact, concepts of integration such as the value stream (Womack & Jones, 1994), and lean supply (Lamming, 1993) are starting to become operational in both manufacturing and service industries (L'Essentiel du Management, 1999). A shift in the perspective of the production chain, from a sequential to a network vision where ICT plays a central role, is taking place. The following topics are challenging management researchers: changing behaviour of suppliers, OEMs, service providers and customers required in the integrated supply network; performance imperatives required by the network organisation; use of information technology to enable improved service levels in terms of delivery speed and customisation; effect of the increasing role of ERP systems (Enterprise Resources Planning) on the role of operations managers and the level of performance of operations; future evolution of ERP systems (taking into account the massive critique in terms of inflexibility and hazardous functioning); impact of real-time sales information on inventory management; effect of changing customer behaviour -for example the increasing use of e-commerce- on the operation of production systems.

Conclusion

Based on the assumption that technology and managerial functions are closely related, impacting each other, the paper emphasised that most research projects and publications within the field of technological management could be clustered into the two main research tracks, namely:

- Managing technology as an activity;
- Managing technology as a resource.
- Further discussion and research will contribute to develop a more structured and comprehensive research agenda, in particular when including R&D but also some support functions such as law and information systems.

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Survey Contributing Colleagues

R. Bah, A. Godener, N. Gonthier, A. Munos, Groupe ESC Grenoble (F)

J.P. Allegret, CNRS-University of Lyon Lumière

R.W. Scapens, University of Groningen (NL)

S. Wattam, The Nottingham Trent University (UK)

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Jean-Jacques Chanaron,
chanaron@esc-grenoble.fr
CNRS, Professor at Groupe ESC Grenoble

Dominique Jolly and Klas Soderquist,
jolly@esc-grenoble.fr
soderquist@esc-grenoble.fr
Professors at Groupe ESC Grenoble

Groupe ESC Grenoble
B.P. 127, 12 rue P. Séward
tel. 33 (0) 476 70 60 60
fax 33 (0) 476 70 61 38
38003 GRENOBLE Cédex 01
France