Considerations for generating and implementing technological strategies

Consideraciones para la generación e implementación de estrategias tecnológicas

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ABSTRACT

Technology is increasingly considered to be a differentiating element leading to competitiveness becoming improved, thereby making it a basic component where efficient management is a key issue in both organisational planning and defining development policy. The managing and taking of decisions regarding technology requires a technology strategy to be generated through a systematic and structured process contributing towards its successful implementation. This article proposes a set of considerations for formulating and applying such strategy; it begins by posing a reference concept and then identifying some academic contributions which have been made in Colombia. Some Colombian cases are then presented referring to the topic at three levels: macro (country), meso (sector) and micro (company). A conceptual proposal called technological strategic octogram is the proposed as a result of this, covering topics such as the contextualising conceptual referents, methodological thoroughness and follow-up mechanisms for this type of processes.

Keywords: Technology strategy, technology management, technological strategic octogram, strategy generation

RESUMEN

Cada vez más la tecnología es considerada como elemento diferenciador que permite mejorar la competitividad, por lo que constituye un componente básico del direccionamiento, donde la gestión ingenieril es clave en la planeación organizacional y en la definición de políticas de desarrollo. La gestión y toma de decisiones frente a la tecnología requieren que la estrategia tecnológica se genere mediante un proceso sistemático y estructurado que contribuya a su exitosa implementación. Este artículo propone un conjunto de consideraciones para la formulación y aplicación de este tipo de estrategias. Plantea un concepto de referencia, luego identifica algunos aportes académicos que se han hecho en Colombia, posteriormente se presentan casos colombianos referentes a la temática en tres ámbitos: macro (país), meso (sector) y micro (empresa), y como resultado ofrece una propuesta conceptual denominada octograma estratégico tecnológico, que abarca tópicos como la contextualización de referentes conceptuales, la rigurosidad metodológica y los mecanismos de seguimiento a este tipo de procesos.

Palabras clave: estrategia tecnológica, gestión tecnológica, octograma estratégico tecnológico, generación de estrategia.

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Introduction

Just as engineering is considered to be fundamental in exploiting technological resources to the full in terms of competitiveness, the role of strategy within a management setting has been widely recognised. Looking at technological management as a field coordinating engineering and administrative knowledge and that from other disciplines for organisations and countries' industrial development, one should thus consider management according to Mora (1996, cited by Restrepo, 2000, p. 2) as, "a global and inclusive institutional function of the forces forming an organisation," thereby highlighting management and leadership abilities. Similarly, the concept of technology may be associated with an organised set of scientific and empirical know-how used in producing, selling and using goods and services (Fundación Vínculo, 2003; Wamken, 2004).

Technological management has emerged from the need for conferring a strategic sense on technology since this factor is becoming increasingly more relevant, passing from being purely operational to being considered as one of the pillars of competitive advantage. Seen from the point of view encompassing Colombia's political, social and technological development, according to Ochoa *et al*., (2007), technological management is the instrument binding the production sector, R&D and technological innova-

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tion. A conceptual and management background is needed for identifying needs and technological opportunities, and implies abilities in managing changes in technology. Engineering management thus plays a key role in this process as a base discipline for developing innovation and decision-making.

According to Linn *et al.* (2000) and Martínez (2002, both cited in Jiménez and Castellanos, 2008), technological management should not be limited to just dealing with needs regarding a set of specific technologies, but also requires formulating and developing strategies based on available resources, current technologies, future markets and the socioeconomic setting. It must also respond to technology transfer, technical changes, standards and quality control. Technology strategy thus constitutes an indispensable element in technology development planning, in identifying, evaluating and selecting technology, generating technological innovation, negotiation, acquiring and contracting technology and selling technology amongst other relevant activities in organisations, sectors and countries.

This article has been aimed at making a conceptual proposing regarding the generation and implementation of technological strategies, emerging from a review and analysis of the literature on the topic within an international setting (presented in the first section), as well as a study of the relevant advances made in Colombia (the second section). The proposal is condensed into what has been called a "technological strategic octogram" (the third section) offering considerations for formulating and implementing technology strategy in similar contexts to that of Colombia.

The concept of technology strategy

Strategy within a setting of technological management is a relatively new concept, forming part of the literature since the end of the 1970s (Adler, 1989) and an area of academic interest before 1980 (Davenport *et al.*, 2003), from then on being considered an emergent area in this setting. Authors such as Dickson and Reick (1993) have shown the absence of a single, integral concept, in spite of slight advances made during the 1990s promoting the concept's coherencies, integrity and orientation (Clarke *et al.*, 1995). Several authors have contributed towards constructing a definition for technology strategy (Appendix A presents a chronological list of the contribution made by some of them).

The concept of technology strategy (TS) presents a broad set of definitions orientated towards understanding it as an inclusive framework, a set of strategic decisions, activities, resources and abilities, a portfolio of options, programmes and long-term plans, a means to an end, a process, etc. This article takes TS as being a *coherent, orientating, unifying and inclusive model of technology contributing towards achieving sustainable advantages through long-term objectives and action programmes, managing decisions related to acquiring, developing, managing and exploiting technology and assigning and managing pertinent resources, thereby allowing an organisation to respond suitably to the opportunities and threats emerging from outside, bearing their strengths and weaknesses in mind***.**

Reviewing the evolution of research regarding TS, it was observed that the main advances and applications regarding the topic have been led by industrialised countries like the USA and Germany, developing countries' contributions being rather more moderate.

Technology strategy in Colombia

There have been some specific developments in Colombia regarding the topic of TS[1]; most of them have occurred during the last ten years, revealing that work in the national academic field has been recent. The predominating approach has dealt with know-how regarding the coordination of corporate strategy and TS, as well as the relationship between the latter and strategic planning.

Most work concerning the topic has been recorded by two institutions.[2] The Universidad del Cauca's Research Group on Regional Models of Competitiveness and the Regional Productiveness and Innovation Centre (Centro Regional de Productividad e Innovación del Cauca – CREPIC) have stated that TS determines guidelines according to which research and technological development project profiles are designed (Sánchez, León, Pemberthy and Robledo, 2008, cited in Fonseca, 2010). Their work has proposed a technology planning model contextualised to the peculiarities of Cauca's small-scale rural agricultural chains. The Universidad Nacional de Colombia's Management, Productivity and Competitiveness Interdisciplinary Research Group (BioGestión) has proposed implementing an intelligent system for generating TS, defined as being an inclusive instrument of technological management tools for searching for, managing and analysing information which (when transformed into know-how/knowledge) leads to the suitable management of resources by generating technological plans and strategies for pertinent/apposite decision-making (Torres *et al.*, 2008).

Some Colombian cases in which this type of strategy has been implemented are now dealt with for practically visualising TS. It is worth mentioning that the cases have not been documented as technology strategy, but are considered to be in the same line of management regarding technology in the long-term.

Cases of technology strategy in Colombia

The Colombian cases presented here are classified into three levels: macro (countrywide), meso (related to a sector-based setting) and micro (company-type setting).

Macro-level technology strategy

Generating and applying strategies for technology management in Colombia has implied knowledge of national reality as well as participation and agreement between a broad set of actors (government, industry, academy, etc.). The topic of science, technology and innovation (STI) has gained relevance within the framework of these dynamics during the last few years as it is considered to be the springboard for the modern world's economic and social development. Regarding this, Colombia has formalised a legal, normative and organisational framework tending to strengthen STI-related processes.

The institutional development of STI in Colombia has gone through three large stages according to the Colombian Planning Department (DNP) and Colciencias (2006). The **first** covers

[1]Sources such as Colciencias' Red *ScienTi* compiling information of Colombian research groups' production, catalogues in the libraries of the main universities in Colombia, the Scielo Colombia index of scientific and technical journals and the proceedings of International Technology and Innovation Management Conferences held between 2008 and 2010 in Colombia have been used for identifying academic work regarding the topic of technology strategy in Colombia.

[2]Other institutions would be the Universidad Javeriana, the Escuela Superior de Administración Pública (ESAP) and the Universidad del Rosario.

1968 to 1989 when human resources and research groups became formed through financing people studying abroad, thereby leading to an increase in the number of scientists as well as investment being made in infrastructure and equipment for research in Colombia. The **second** stage was developed between 1990 and 1999 when the first law of Science and Technology was promulgated and the Colombian System of Science and Technology was formed leading to coordinating scientific and technological activities with the requirements and problems of different sectors in national life (DNP, 2000). The formation of centres of technology development (CTD) and Colombian research centres (CENI) were also promoted. Document 2739 produced by CONPES (Consejo de Política Económica y Social) dealing with science and technology appeared in 1994; this approved Colombian science and technology policy 1994-1998 as a key element in internationalising the economy.

The third stage covers 2000 to date, characterised by being a period of consolidation regarding abilities/capacity created in the service of Colombia's economic and productive development. CONPES 3080 formulated a policy framework centred on coordinating and strengthening the Colombian System of Science and Technology for 2000-2002 which led to the creation of the Colombian Productivity and Competitiveness Fund. CONPES 3280/2004 proposed alternatives for improving information, coordination and complementariety of sources and support instruments for companies, as well as follow-up for and evaluation of the results obtained (Malaver, 2005). Colombian science, technology and innovation policy was promulgated in 2009 (law 1286 - CONPES 3582), thereby transforming the former Instituto Colombiano para el Desarrollo de la Ciencia y la Tecnología (Colciencias) into the Science, Technology and Innovation Administrative Department and strengthened the Colombian System for Science, Technology and Innovation, seeking to increase Colombia's capacity for identifying, producing, disseminating, using and integrating scientific and technological knowledge, aimed at improving competitiveness and contributing towards Colombia's productive transformation.

The foregoing reveals the existence of science, technology and innovation policy and activities in Colombia which have in some way promoted technology development. The normative framework encompasses elements forming part of the TS such as adapting technology for promoting innovation in the Colombian production system, the availability of financial resources through investment in STI and the production and use of scientific and technological knowledge for resolving scientific and business problems.

Meso–level technology strategy

At sector level, the efforts made by the Ministry of Agriculture and Rural Development, the Ministry of Trade, Industry and Tourism and other regional entities such as the CREPIC may be highlighted.

A set of strategies for improving productivity and efficiency regarding production have been put in motion in Colombia, aimed at consolidating agribusiness sector recuperation and growth. Once such strategy is to promote research, transfer and innovation of technology. The Ministry of Agriculture and Rural Development has thus sought to prioritise technological and non-technological needs by preparing prospective technological R&D agendas for the Colombian agribusiness sector. These have emerged as the most recent mechanism for defining the sector's requirements for investing in STI, conceived as being an integrated, dynamic and flexible programme of projects and strategies supporting production chains' sustainable and competitive development (Castellanos *et al*., 2009, Castellanos, Fonseca and Ramírez, 2011).

A four-phase structured process thus began in 2006, each phase lasting one year. The first was the pilot cycle in which milk-product, fish-farming, forestry and cacao-chocolate production chains/sectors participated, agendas being finalised in 2007. Phase two (2008) consisted of the first cycle in which fruit (Physalis and mango), potato, palm, rubber, fique (a natural fiber), shrimp, herb/spice and beef production chains participated. Phase three (cycle 2) involved panela (brown cane-sugar) producing, flower-growing, pig-farming, sheep-goat farming, vegetable-grower, bee-keeping and cotton farming chains and the cross-sector topic of food safety in Colombia. The fourth stage (regional cycle) involved pitaya (cactus fruit) chains in the Valle del Cauca, granadilla (Passiflora) in Huila, trout-farming in Antioquia and wooden-furniture-making in Bogotá.

The Ministry of Trade, Industry and Tourism has promoted technology and industrial forecast studies since 2007 in different sectors such as the software industry and its associated services, the cosmetics and cleansing products chain, the domestic appliances chain and the pulp, paper and the graphic and industrial arts publishing chain for strengthening the formulation of strategies and identifying actions leading to improving technological capacity, for defining the short-, medium- and long-term future of different production sectors, as well as the pertinent integration mechanisms for achieving technological development.

An ordered, logical and systematic process has been required in both types of initiatives and they have become a specific and contextualised methodology regarding the system of technological intelligence proposed by Castellanos *et al.* (2005). CREPIC applied the technological planning method (in 2008) for generating a technology plan for Cauca's fish-farming chain.

Micro–level technology strategy[3]

Greater acceptance of implementing TS in particular organisations in Colombia has been shown by large companies compared to small- and medium-sized ones where the topic has still not been considered to be strategic. The rol of the Colombian Institute of Petroleum (Instituto Colombiano del Petróleo - ICP), which is the R&D Centre of Ecopetrol (Colombian company of petroleum) is relevant; this entity is responsible for directing technology strategy and business know-how, having eight technology programmes in the business chain. It has a planning and technology strategy unit within its organisational structure which deals with implementing technological management and innovation, as well as strategic technology plans and preparing the company's technology strategies (Ecopetrol, 2010).

The Corporación de Ciencia y Tecnología para el Desarrollo de la Industria Naval, Marítima and Fluvial (COTECMAR) has a strategic managing unit orientated towards technological R&D and innovation activities through which it has formulated its TS (Quintero and Sejnaui, 2010). Interconexión Eléctrica SA (ISA) began formal technology management in 1999 for improving process productivity and efficiency based on a model constructed through the participation of all areas of the organisation. The model is founded on five activities: technology strategy, technol-

[3]The cases of micro-level technology strategy resulted from a search of secondary information sources using the key words: "technology strategy."

ogy plan, acquiring technology, R&D and transfer and assimilation regarding technology (Boletín ISA, 2004).

According to the aforementioned cases TS is clearly a key element in organisations' competitiveness at different levels; even though it has been shown that practical developments regarding the topic have been mainly centred on macro and meso levels in Colombia this has not filtered down to the micro level in any significant way, leaving this important field open to exploration. It should be recognised that TS does not represent fulfilling expectations in themselves since their success depends on their suitable formulation and implementation.

Considerations for generating and implementing technology strategy

It may be stated that there is no universal formula for generating and implementing TS. Even when several models and methods have been developed they are subject to the peculiarities of the context framing each organisation.

A technological *strategic octogram* is now proposed (Figure 1) resulting from analysis and synthesis of contributions to the topic available in the literature, consisting of eight considerations for generating and implementing technology strategies in organisaions. Such considerations include particularities according to the application setting (for example, developed or emerging economies) and where the involvement of different actors and disciplines is decisive for their operationalisation, highlighting the role of engineering as a set of knowledge leading to generating and using technological solutions to specific problems affecting organisations regardless of their level (macro, meso or micro).

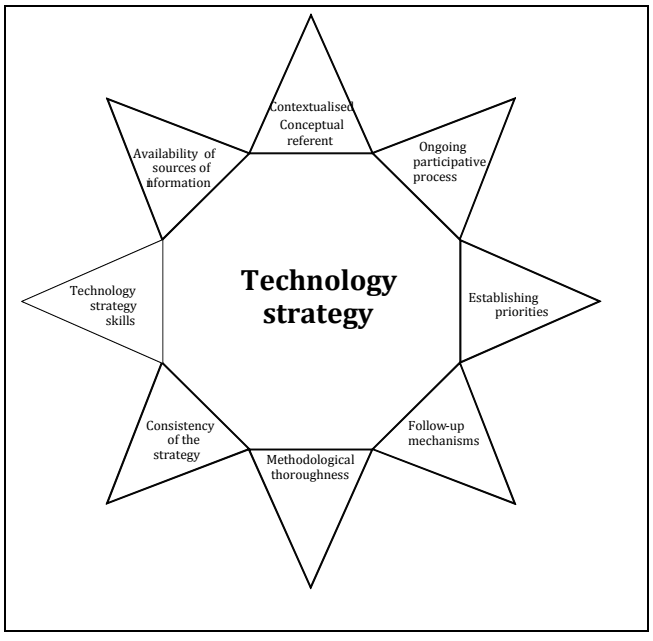

Figure 1. Technological strategic octogram (Fonseca, 2010).

a) *Contextualised conceptual referent*: This deals with the challenge represented by academic validation of existing theories (most referring to the context of developed countries), so that conceptual referents are proposed which have been adapted to a specific application setting. Greater efficacy may thus be achieved in generating and implementing TS and, in the long-term, the consolidation of a school or line of thought regarding the topic.

b) *Methodological thoroughness*: a lack of a logical and systematic process for generating TS is frequently recognised in emerging economies' organisations. Strategy effectiveness may become reduced as a consequence of the lack of structure and know-how regarding the minimum steps for generating and implementing TS, thereby increasing the probability of determinant TS elements being left aside and restricting an organisation regarding a culture of planning, feedback and follow-up, given the informal nature of the process. It is thus fundamental that generating TS is done within the framework of a duly structured process.

c) *Availability of sources of information*: the optimum condition regarding the need for information is that sources are available for obtaining it and, when necessary, the resources for acquiring such information (such condition is easily fulfilled for organisations from developed economies, but not so for those which are not). An emergent economy intending to initiate the formulation of technology strategy must seek to identify sources of freely-available information through which information can be obtained from an external setting, or by establishing alliances with institutions possessing such sources. An important number of sources of this type are currently available (perhaps as yet unknown). An ongoing culture of systematisation of technological information must also be established within an organisation to keep it updated as the basis for formulating TS.

d) *Ongoing participative process:* TS is generated and implemented by people, and thus of great relevance that the process be participative since the beginning. This will ensure legitimacy for the TS proposal being generated, contribute towards the appropriation of strategy, preparing the way for its implementation and will lead to ensuring that TS becomes sustainable. The process must likewise have the leadership of people taking strategic decisions at the highest level, since they must have a broad vision of the system and their participation must also reflect the importance of TS, thereby contributing towards committing a greater number of people.

e) *Contextualised technology strategy skills*: the strategy formulation and implementation leader must, preferably, have know-how in the field of management, specifically in technology strategy, and in the field of technology. Such person must preferably have had an academic formation in administration and engineering or related areas of study. One is dealing with a team of strategists which could be interdisciplinary but within the framework of the proposed academic profiles. Specific skills are also required, such as a disposition for applying structured methodologies, facility in searching for and managing information, analytical skills, flexible thinking, anticipation ability, long-term vision, thinking based on total integration regarding a determined situation, verbal communication and persuasive ability skills.

f) *Establishing priorities*: economic resources may limit technology projects, meaning that they must be structured from investment priorities which are suitable covering technological needs for promoting the proposed objectives. Prioritising resources emerges from analysing internal economic resources available for working with technology, without forgetting to detect external support, such as support/aid from government and international entities.

g) *The consistency of a technology strategy with overall strategic guidelines*: an attempt must be made to avoid incoherencies

or lack of coordination between TS and corporate and business strategies and also between technology strategies formulated for other application settings (macro, meso and micro). Formulating a TS lacking knowledge of other types of strategy could be very inefficient and must thus be directly related and take account of corporate strategic guidelines.

h) *Follow-up mechanisms*: strategies may often be generated but their real application may not be achieved. Based on an analysis of the models and methods in the available literature, a definition of follow-up mechanisms is proposed contributing towards guaranteeing the implementation of formulated TS. Such mechanisms would include periodic evaluation of activities regarding TS for evaluating the impacts and identifying aspects to be redefined or adjusted, thereby making the process dynamic.

The technological strategic octogram can thus be useful for approaching and defining technology strategies at distinct levels (macro, meso and micro) within a framework of developing country, regional, sector or company initiatives.

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Appendix A. Authors' contributions towards defining technology strategy

Year	Author	Definition of technology strategy
1980	Kantrow, Alan M	Provided an inclusive and integrated framework, necessary for visualising a company's technology within the context of its overall business orientation
1983	Porter	A set of company decisions covering three dimensions: technological aggressiveness, automation and innovation and developing new products/services
1985	Birbaum Philip	Involving long-term objectives in development or acquiring new innovation entries and outlets
1988	Ford, David	Covered acquiring, managing and exploiting technological knowledge and resources by an organisation for achieving its business objectives and technological goals
1988	Maidique Modesto and Patch, Peter	Consists of a portfolio of options and plans allowing an organisation to respond effectively to technological threats and opportunities
1989	Weiss, Andrew and Birbaum Philip	Defined a long-term programme of technological change in an organisation and its implementation would include establishing the strategic activities necessary for systematically obtaining the technology required by an organisation for developing an overall business strategy
1989	Malekzadeh, Ali. R and Bickford, Deborah	A set of strategic decisions and actions required for managing and transforming input into output, aimed at increasing competitive advantages
1989	Adler	A decision-making model bringing together technological goals and the main technological means for achieving them. Guidelines for the use of resources and technological capacity
1989	Mark Dogson	The means of obtaining and maintaining a significant competitive advantage in the modern market
1990	Pavitt Keith	A set of options which must be drawn up for technological development
1992	Spital, Francis C and Bickford, Deborah J	A set of strategic decisions and actions required by managers for transforming input into output for achieving competitive advantages
1992	Jaime, E and Barron, L	The way companies select, acquire, assimilate, adapt, improve and design and develop technology for generating competitive advantages
1993	Reick, R.M and Dickson, K.E.	The process throughout which firms use their technological resources for achieving corporate objectives
1994	Martin J. Read and Anthony E. Gear	Dealing with decision-making for developing, exploiting or the technologies defined by an organisation
1995	Clarke, Ken, Ford, David, Saren, Mike, Thomas, Richard	Covers the decisions related to sustaining a company's technological basis
1996	Shaker Zhara	A plan guiding a company's decisions about developing, accumulating and deployment of resources and technological capacity
1999	Shaker Zhara, Rajendra Sisodia and Brett Matherne	A set of company resources and abilities providing the distinct skills necessary for enabling it to develop its corporate strategy
1999	Hidalgo, Antonio	Makes a company's technological options explicit (i.e. those related to the intensity of technological efforts, the distribution of resources and competitive position)
2001	Solomón, Julia	Covers three main activities, namely: acquiring or exploiting technology, managing and exploiting technological knowledge
2001	Chiesa, Vitorrio	Designs a "trajectory" defining how resources and technical knowledge are acquired and internalised
2002	Basant, R and Chandra, P	Reflects a company's options regarding the selection, specialisation and incorporation of technology, the sources of technology and the means for creating capacity/ability. Their overall objective is to guide a company in acquiring, developing and applying technology for achieving competitive advantages
2002	Pere, Escorsa and De the Puerta, Enrique	Using technology for obtaining a sustainable advantage over the competition
2003	Davenport Sally, Campbell-Hunt Colin and Solomon Julia	Points out three large-scale activities: acquiring, managing and exploiting technology and technological knowledge for the benefit of an organisation
2006	Porter	Deals with the way in which a company approaches development and the use of technology
2006	Haro, María del Carmen	A series of policies, plans and procedures for acquiring technology, managing it within a company and exploiting it for achieving its technological and corporate objectives
2008	Pedroza Álvaro and Ortiz Sara	Implies choosing the most pertinent technologies for a company to invest in first
2009	Ghazinoory Sepehr, Divsalar Ali and Soofi Abdol	Management decision-making model related to the use of the main technological instruments and their goals for achieving a company's particular business objectives through which priority cab be assigned to future corporate technological plans

Source: constructed from Kantrow (1980), Porter (1983), Birbaum (1985), Ford (1988), Maidique and Patch (1988), Weiss and Birnbaum (1989), Adler (1989), Dogson (1989), Pavitt (1990), Spital and Bickford (1992), Jaime and Barron (1992), Dickson and Reick (1993), Read and Gear (1994), Clarke et al., (1995), Zahra (1996a, and 1996b), Hidalgo (1999), Solomon (2001), Basant et al., (2002), Escorsa et al., (2002), Davenport et al., (2003), Porter (2006), Pedroza and Ortiz (2008), Ghazinoory et al., (2009)