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Estrada, Salvador; Cano, Karen; Aguirre, Joao

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How is technology managed in SMEs? Differences and similarities between micro, small and medium enterprises

¿Cómo se gestiona la tecnología en las pymes? Diferencias y similitudes entre micro, pequeñas y medianas empresas

Salvador Estrada[1*], Karen Cano[1], Joao Aguirre[2]

[1] *Universidad de Guanajuato, México*
[2] *Strategic Intelligence, Australia*

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Abstract

In the field of innovation and technological development, regularly small and medium enterprises (SMEs) do not have the required resources to start projects. The innovative and technological behavior is conditioned by several elements, such as structure, financial resources, the environment and the sector. Each one presents competitive conditions that predetermine their possible strategies and behavior. For an efficient management of technology, it is necessary to consider the opportunities and threats of its technological position, the capability to acquire and develop resources, the capability to assimilate technologies and learn from this experience. In practice, the SMEs establish different models. The present work aims to characterize the different functions carried out from certain models established in the literature. From a representative sample of 81 companies and through a cluster analysis, we were able to identify 6 different empirical models defined by differences and similarities in the analysis of the environment, market research and technology assessment, acquisition and adaptation of technology, assimilation and technology implementation, which are mediated by size, sector and location.

JEL Codes: M10, M 20, O30
Keywords: Learning orientation; Innovation; Firm performance.

*Corresponding author.
E-mail address: salvador.estrada@gmail.com (S. Estrada)
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Resumen

En el ámbito de la innovación y el desarrollo tecnológico, las pequeñas y medianas empresas (Pymes) muchas veces no cuentan con los recursos necesarios para iniciar proyectos. El comportamiento innovador y tecnológico está condicionado por una serie de elementos, tales como la estructura, los recursos financieros, el entorno y el sector. Cada uno presenta condiciones de competencia que predeterminan sus posibles estrategias y conducta. Para una eficiente gestión de la tecnología es menester considerar las oportunidades y amenazas de su posición tecnológica, la capacidad de adquirir y desarrollar recursos, la habilidad para asimilar las tecnologías y el aprender de esta experiencia. Las Pymes establecen en la práctica diversos modelos. El presente trabajo pretende caracterizar las diferentes funciones llevadas a la práctica a partir de ciertos modelos establecidos en la literatura. A partir de una muestra representativa de 81 empresas y mediante un análisis de conglomerados, se lograron identificar 6 diferentes modelos empíricos definidos por diferencias y similitudes en el análisis del entorno, investigación de mercados y evaluación de tecnología, adquisición y adaptación de la tecnología y asimilación e implementación de tecnología, los cuales están mediados por el tamaño, el sector y la localización.

Códigos JEL: O3, D41
Palabras clave: Pequeñas empresas, conducta tecnológica, innovación.

Introduction

For Mexico, SMEs represent a growing sector as they contribute with the production of around 32% of the Gross Domestic Product (GDP). The economic significance is obvious; however, it being a very dispersed and diversified sector of the economy, there is still a lot of volatility in the creation and growth of these enterprises. According to data from Adecco (2016), the probabilities of success in the local market are in the average range of between 25% and 30% below the world average of 40%.

From a strategic perspective, the resources and capabilities developed by SMEs suffer from skills shortages, poor management practices, and limited training of their workforce. They are also not very exposed to global best practices in quality, design, or production (Farid, 2017). This situation translates into variable performance in profitability, survival, and growth.

In the areas of Innovation, Research, and Technological Development, SMEs are affected because they often do not have the necessary resources to start R&D projects. According to a recent IDB report (2010): *"A substantial number of enterprises in the region define themselves as innovative, and practice innovation in one way or another"*. According to various surveys conducted in Ibero-America, the rate of innovative enterprises in processes is considerable (approximately in the range of 15-40%) (Peirano, 2007; Anlló and Suárez, 2008, Marins, Anlló and Schaaper, 2012). However, there is still a wide technological gap with leading countries and, many times, these innovative efforts represent a response to the growing competitive challenge derived from globalization.

In a majority of cases, SMEs in Latin America have carried out technology management to meet the requirements of basic or generic technological resources that allow them to enter and remain in the market. Due to this there is no functional structure in charge, no technological plans or agendas are developed, and there are no specific budgets for these activities (Malaver and Vargas, 2004). Recent literature on technology management in SMEs highlights the effort to generate evaluation frameworks on the type of strategy implemented (Bolukbas and Guneri, 2017),

as well as the impacts of this activity on business performance in terms of cost reduction (Burggräf, Dannapfel, Bertling and Xu, 2018), differentiation (Loon and Chik, 2018), response to customers (Zhu, Zou and Zhang, 2018; Hills and Atkinson, 2016), efficiency (Lohmüller and Petrikhin, 2018), development of talent and skills (Bolukbas and Guneri, 2016; Van Der Veen, Perez and Sabbatinelli, 2016; Nordin and Adegoke, 2015), integration and cooperation (Noh and Lee, 2015), but in particular for the development of absorption capacities (Garengo, 2018), successful adoption of emerging technologies (Burggräf, Dannapfel, Bertling and Xu, 2018; Deranek, Chopra and Mosher, 2017; Niaki and Nonino, 2017), as well as skills to anticipate promising applications and future developments (Bullinger, Bauer, Ardilio and Seidenstricker, 2015).

Faced with an increasingly turbulent and highly competitive environment, the question arises as to whether the informal intention of the strategy can move towards more formal management of technology, development of functional capacities, and practices constituting the technological heritage, linkages, and knowledge safeguards. Thus, the objective of this research work is to conduct a study of technology management in order to know the current situation of SMEs in Mexico and more specifically, in the state of Guanajuato. In order to carry it out, the present document is organized in the following manner: in this section, an introduction of the subject matter is given; in the second section the theoretical framework is elaborated, then the methodology is developed to give way to the results in the fourth section; and in the last part, the discussions and conclusions are presented. Based on four basic functions of technology management in SMEs, there are six patterns that express differences in size and location and reveal different degrees of sophistication, which can advance a proposal on a dynamic growth pattern based on technology management practices.

Theoretical framework

Technology management emerged as a response to the need to manage the technological factor with a strategic sense. It is defined as the process of managing all those activities that enable the enterprise to make the most efficient use of the technology generated internally and that acquired from third parties, as well as to incorporate it into new products (product innovation) and the ways in which these are produced and delivered to the market (process innovation). It deals with decision-making problems at all levels related to the creation and use of technological assets and capabilities; their impacts on individuals, organizations, societies, and nature; and the reconciliation of the economic, social, and environmental consequences of technological innovations (Bayraktar, 1990).

Technology management seeks to improve the capacities of absorption and internalization of knowledge for which it can use methodologies that support these activities (Medellín, 2010). Therefore, management models are tools for decision-making on innovative strategies (Mendoza and Valenzuela, 2014). Next, six models are discussed that seek to guide correct practice, which can be carried out by both SMEs and large enterprises. (01) The main objective of the PNT (National Technology and Innovation Award, 2012) model is to promote the development of organizations of any size or type, in order to project them in an orderly manner at world-class competitive levels through sustained and systematic explicit technology management. It is composed of a series of processes and functions.

(02) The COMECYT model (Cuevas, León and Ramírez, n.d.) establishes as a permanent solution basing the elaboration of products and services on the organizational capacity and

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skills to create, store, transfer, apply, and disseminate knowledge through formal networks. The model is represented with a spiral, the core part of which is innovation, providing essential importance to creativity, quality, added value, and entrepreneurial attitude. This model should be a coordination tool for human capital, in addition to be a means to set and achieve goals in product development.

(03) The Sumanth and Sumanth model (1996) proposes a systemic approach to technology management, through a continuous process that can be applied to the product, service, workplace, and national or international corporation.

(04) The Hidalgo, León, and Pavón model (2002) defines a set of specific management processes adapted to technology to identify, evaluate, select, acquire, assimilate, and efficiently use it. Each business sector will have to adjust these procedures to its needs. (05) The COTEC model (1998) (Foundation for Spanish Technological Innovation, the company SOCINTEC, CENTRIN (University of Brighton), IRIM (University of Kiel) and the R&D Unit of Manchester Business School) is based on an uncomplicated structure covering five elements or functions. Each element can be assisted by various tools for its implementation such as market research, SWOT analysis, technological foresight and forecasting, competitive intelligence, the value chain, project evaluation and management, portfolio management, cause and effect diagram, intellectual property management, value analysis, change management, or the management of talent and knowledge, among others. (06) Antonio Hidalgo (1999) exposes technology management in his model as a strategic factor of industrial competitiveness. He emphasizes the functions, as well as the essential tools of the technology management process. The model classifies the functions for developing technology management efficiently into active and support functions.

In sum, common stages and/or activities are found in the 6 models researched (the model referenced is in parentheses) such as:

•Analysis of the environment: (Anticipating the efficiency, optimization, and simplification)

(01) (03) (05) Surveillance of the environment through an organized, formal, selective, and systematic process in order to make decisions with less risk and anticipate changes.

(04) (06) Identification of the technological potential in terms of market needs and main competitors.

(02) Discussion of the idea with the technology, capital, and operational partners.

•Market research and technology assessment (develop criteria to improve competitiveness).

(01) (02) (03) (04) (05) Selection of the most appropriate technologies, taking into account factors such as availability, cost, relationship with other technologies, etc.

(01) (05) (06) Channel resources by identifying critical technologies, selecting lines of action, and drawing up a technological plan.

•Acquisition and adaptation of technology (deployment of technical tools and provision of technological resources).

(01) (02) (04) Identification and evaluation of suppliers and supplies.

(06) Increasing the technological heritage (examining external possibilities before deciding to carry out development internally).

(02) (05) Training (once the technological option has been chosen, the enterprise has to allocate the necessary resources to materialize the chosen option); incorporation of research personnel.

(02) Implementation of experimentation infrastructure at laboratory level and later escalation to the industrial plant.

(02) Carrying out R&D projects.

(02) Exogenous factors such as technical assistance, financing, linkage.

•Assimilation and implementation of technological heritage (improve competitive position by accumulation and implementation of technological capabilities).

(02) (05) (06) Realization of innovation projects until the final launch as a new product or service.

(02) Indicators to measure innovation performance, as well as technological, organizational, financial, and social impacts.

(01) (02) Safeguarding and caring for technological heritage through trademark and patent protection.

(02) exogenous factors such as dissemination (promotion of innovation to generate a quality image of the same).

(03) (04) Improvement of the acquired technologies adapting them to their particular needs, which entails the training of personnel and the establishment of internal procedures.

(03) Important decisions regarding the obsolescence of a given technology.

(05) Learning (cataloguing the experience of success or failure). According to Faloh Bejarano (2006), a good technology management system must be reflected in the model used, which is supposed to simplify or approximate the real system. The restrictions are related to the characteristics of the enterprise, its strategies, the type of products or service it sells, profit margins, the nature of the technologies, the level of control it has over them, attention to the environment, investments in R&D, innovation activities and their effect on the operation of the enterprise. SMEs may be unable to exploit new products due to limited organizational and marketing capacities (Cobbenhagen, 1999). Filson and Lewis (2000) and Freel (2000) analyze cultural barriers to innovation, such as resistance to change, the tendency to ignore the process, focus on short-term needs, lack of strategic vision, and the diffusion of a blame culture. The tendency to ignore procedures (to not take responsibility), the absence of process supervision activities, and poor management are problems that impact the innovation process defined as a sequence of tasks. The study by Scozzi, Garavelli, and Crowston (2005) reviews the literature on these issues and their impact on innovation. The lack of monitoring of technology, search functions, and organizational memory are mentioned as significant issues in studies that interpret the innovation process as a flow of decisions. An important problem, which is also considered, is the lack of a strategic vision to drive the development of innovation (Bullinger, Bauer, Ardilio and Seidenstricker, 2015). The problems associated with the creative perspective, such as the existence of a guilt culture, depend on the abilities and capabilities of the entrepreneur and are, therefore, not common to all companies (Scozzi, Garavelli and Crowston, 2005).

In their study on technology management in high-tech SMEs, Loon and Chik (2018) suggest that there is a range of companies among those seeking efficiency and innovation. On the other hand, Lohmüller and Petrikhin (2018) establish that this management requires different management roles and that its different implication would originate different arrangements and results. In this same sense but emphasizing the managerial capacities and incorporating also the technological infrastructures, Bulokbas and Guneri (2018) find different levels of technological competences for the case of the Turkish manufacturing SMEs.

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Thus, a proposal for the study to be undertaken can be derived:

P1. The SMEs of the industrial sector in the state of Guanajuato make up different empirical patterns of technology management according to their size, sector, and location.

Methodology

Based on the technology management literature, that is, from the definition and essential criteria for the practice of this, incorporating in turn the activities and phases of the models mentioned above, this study aims to know whether the activities are more attached to any of the six models or if SMEs carry out this activity empirically.

Empirical research was conducted using a quantitative explanatory and cross-sectional approach through Variance Analysis (ANOVA) and Hierarchical Cluster Analysis (HCA). In this study, technology management in industrial MSMEs was analyzed, using the variables size, sector, and location as control. Similarly, Tukey's test was applied to ANOVA with the intention of finding the sources of the statistically significant differences between the groups, taking as reference the size factor of the companies under study. In SME innovation studies, cluster analysis has been very useful to determine differences in business perception of barriers to innovation (Marin, Marzucchi and Zoboli, 2015), sources of information supply and knowledge in open innovation (Brunswicker and Vanhaverbeke, 2015), the degree of openness (Othman Idrissia, Amaraa and Landrya, 2012), the usage level of e-commerce (Sila and Dobni, 2012), marketing and sales activities in product strategies (Cant, Wiid and Kallier, 2015), as well as the level of technological competence (Bolukbas and Guneri, 2018).

Design of the sample and data collection

For the development of this research work, the database offered by the Mexican Business Information System (2013) was taken as reference, in which, as of November 25, 2013, for the state of Guanajuato, a total of 15,507 companies are registered for the agricultural, construction, and manufacturing sectors of the municipalities of Leon, Silao, Guanajuato, Irapuato, Salamanca, and Celaya, from 1 to 250 workers, universe that is reduced to 951 companies with the exclusion criterion of having an e-mail. Therefore, the survey was designed based on the theoretical models analyzed, as well as general information of the enterprise, to be answered by managers or owners of MSMEs in the industrial sector of Guanajuato, given the case that they could not attend the survey, it was also taken by management personnel and/or production managers, and was applied randomly with a 95% confidence level and a 5% margin of error; a total of 284 surveys were sent out and applied in three waves in the period from December 2013 to August 2014. The tool used for data collection was an online software called SURVEYMONKEY, where an invitation to participate was sent to respondents via email. Some others were by means of telephone calls and scheduled attendances by means of appointments to the companies. The answers were emptied to the statistical analysis software SPSS V.17. A response rate of 30% was obtained, with a total of 81 valid surveys at the end.

Table 1.
Distribution of the sample by size, sector, and place of activity

Size	Number of enterprises	Percentage
Micro	26	32.1
Small	34	42
Medium	21	25.9
Total	81	100
Sector	Number of enterprises	Percentage
Food, beverage, and tobacco industry	11	13.6
Textiles and clothing	3	3.7
Wood industry and wood products	2	2.5
Paper Products, Printers, and Publishers	1	1.2
Chemicals and petroleum products	2	2.5
Basic metal industry	17	20.9
Metallic products, machinery, and equipment	11	13.6
Construction	25	30.9
Agroindustry	9	11.1
Total	81	100%
Municipality	Number of enterprises	Percentage
Celaya	17	21
Irapuato	11	13.6
León	26	32.1
Guanajuato	9	11.1
Salamanca	16	19.8
Silao	2	2.5
Total	81	100

Source: own elaboration.

Table 1 shows the distributions of the sample by sector, stratum of size according to the number of employees, and location. As can be observed, the sector best represented is that of small companies with 42%, while sector-wise it is that of construction reaching almost 30%, while Agroindustry reaches 11.1% and Manufacturing 58%. The composition of the sample is consistent with the specialization of the region.

Measurement of variables

After the review of the literature, the operationalization of variables was elaborated, and it was established that the theoretical models can be synthesized in four functions: Environmental analysis, Market research and technology evaluation, Acquisition and adaptation of technology, and Assimilation and implementation of technological heritage.

Based on the similarity of the phases of the previously mentioned and detailed models, a questionnaire with 4 sections was prepared. After the introductory section where the objectives and scope of the research are presented, the entrepreneur begins the thematic sections. The following table shows the composition of the survey where the constituent variables of each section are mentioned, as well as the type of variable used.

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Table 2.
Composition of the survey.

Sections	Variables that comprise it	Type of variable
General data of the enterprise	Enterprise name, address, e-mail address, subsector, seniority, nature.	Nominal
Environment and needs of the enterprise	Elements for environmental analysis, sources of information, frequency of environmental analysis.	Ordinal
Acquisition and adaptation of technological heritage	Types of technology, criteria for acquiring technology, areas of R&D integration, human resources, financing, infrastructure.	Ordinal
Technology Assimilation and Implementation	Source of change, motivation for change, impact of change, technology lifecycle, reputation.	Ordinal

Note: for metric variables a Likert perceptual scale to indicate frequency or importance of the activity was used.

Statistical Analysis

Frequency distributions were obtained for each variable for the sample and subsamples by size. They were grouped according to technological phases. Variance Analysis was applied to find significant differences. Tukey's test was applied to determine the size of origin.

In order to go even deeper and determine with certainty how technology management is managed among micro, small, and medium-sized enterprises (MSMEs), a statistical method was applied that shows the behavior of a group based on the similarities presented by the cases. By means of a cluster analysis, the sample was classified into a small number of groups in such a way that the observations belonging to one group were very similar to each other and very dissimilar from the rest. In order to obtain the number of groups to be analyzed, Ward's method was used where 6 clusters were obtained.

Results

A series of summary tables presented by stages of technology management are explained below. The highest percentages of each variable are indicated, in terms of greater frequency or importance, as well as the variables that present significant differences between enterprise sizes.

Table 3.
Stage 1. Analysis of the environment.

Internal analysis	Elements of the External Analysis	%	Most important sources of information	%
90%	Suppliers	76.6	Company News	56.8
	Customers	75.6	* Supply channels and suppliers	55.5
	Employees	74.1	Supplier websites	54.3
	* Market	67.9	Competition (new product launches)	53.1
	* Investors and partners	37.1		

*Variables with a significant difference between enterprise sizes.

The first phase of technology management carried out by SMEs in the industrial sector of the state of Guanajuato is the Analysis of the Environment, where 90% of the SMEs carry out this internal activity at least once a year. In terms of the elements of the environment considered for the analysis suppliers, customers, and employees are important. However, the elements for which there are significant differences between SMEs according to the Variance Analysis (not

shown in this article for brevity) are the market and investors and partners. Following the results of Tukey's test, it is revealed that for medium-sized enterprises the market is more important than for small enterprises, while investors or partners is a differentiating element with respect to microenterprises. As far as information sources are concerned, they have a specific weight in the analysis of the environment, but they are somewhat diversified, between public, specific, and inter-organizational sources. For microenterprises, the information obtained from supply channels and suppliers is a differentiating element.

Table 4.
Stage 2. Market research and technology assessment.

R&D activities	%	Type of technology	%	Technology acquisition criteria	%	Integration of R&D in the enterprise	%
Last 5 years	66.7	ICTs	46.9	Specialization	54.4	Maintenance	86.4
Last 3 years	66.7	Transformation	46.9	* Technical study	53.1	* Sales	84.9
Last year	66.7	Manufacturing	45.7	Price	49.4	Quality	81.4
		Process	45.7	Financial Evaluation	47	Production	80.2
		Transport	45.7	Competition	45.2		
		Packaging	43.2	Macroeconomic context	35.8		

Variables with a significant difference between enterprise sizes.

The second phase of Market Research and Technology Assessment (FII) reveals that two thirds of the SMEs studied are persistently carrying out research and development activities (68% of the sample is more than six years old, and by the invariant percentage we noted that those who predominantly declare this activity are the oldest companies). They do not show a special dependence on one type of technology but rather have their attention diversified without highlighting any level of importance. There are also multiple concepts they consider for the acquisition of technology. When it comes to the criteria for acquiring technology, there is a significant difference between the sizes of companies, with the result that it is even more important for micros to carry out technical studies than for medium and small companies. On the other hand, the R&D activity is not centralized but is a distributed competition between maintenance, sales, quality, and production activities. It was also found that a differentiating element for the microenterprise is the level of integration of R&D with sales.

The stage of acquisition and adaptation of technology reveals that SMEs dedicate personnel to solve problems systematically and to the adaptation and improvement of products and processes (this is how R&D is defined by this type of enterprises). Nearly half of them recruit personnel for this activity. Of the current plant, a little less than half have higher education (a quarter have a bachelor's degree, and a fifth have a postgraduate degree), accordingly there is the expectation of preferably employing bachelor's degree graduates in order to develop primarily technical work (less than five percent visualize an exclusive dedication to research). Half of the SMEs have some supporting infrastructure, mainly laboratories (e.g. quality, analysis, or testing) and maintenance workshops. Research resources come from the enterprise itself. When external services are contracted, the university is privileged. Thus, the alternative strategy for developing technology providers is through its own resources in collaboration with the university.

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Table 5.
Stage 3. Acquisition and adaptation of technology

Recruitment of personnel for R&D activities		**HR earmarked for R&D activities %**		**Level of education %**		**Type of activity to be developed %**	
44.5%		Bachelor's degree	25.9	Bachelor's degree	90.1	Technical	93.8
Infrastructure %		Master's degree	11.1	Master's degree	9.9	Research	4.9
Quality Laboratory	14.8	Specialty	9.9	Ph.D.	0	Support	1.2
Maintenance workshops	14.8	High School	9.9	**Latest technology acquisition %**		**Status of the acquired technology %**	
Physical-chemical analysis laboratory	6.2	Technical School	7.4	6 months	40.7	New	85.2
Pilot Plant	4.9	Ph.D.	2.5	1 year	45.7	Used	14.8
Information centers	3.7	**Impacts due to the introduction of technology %**		2 years	9.9	**Use of supports according to their importance %**	
Testing Laboratory	3.7	Increase in productivity	45.7	3 years or more	3.7	✳ Technological modernization	17.3
Source of the technology %		Change in the process	39.5	**Source of funding for R&D %**		Training and productivity	17.3
Suppliers	87.7	Reduction of work costs	35.8	Own resources	93.8	✳ Improvement of quality	16
Employees	4.9	Efficient use of inputs	30.9	Government	2.5	Patent search and technological services	12.3
Institutions (I.C., universities)	3.7	Increase in production scale	18.5	Banks	2.5	✳ Research with universities, research centers	8.6
Customers	3.7			Other enterprises	1.2	Commercialization and export	6.2
Collaboration with third parties for R&D %							
Public Universities	86.4						
Enterprises	8.4						
Research centers	4.9						

* Variables with a significant difference between enterprise sizes.

In terms of technology acquisition, SMEs mostly operate with modern machinery and equipment, with four out of five companies acquiring technology in the last two years and mostly under new conditions. The vast majority acquire it through market transactions with specialized suppliers. The impacts of technology acquisition are diverse—in order of importance, productivity, process improvement, costs, and efficiency. Two out of ten companies have received some type of support, preferably for modernization, training and productivity, as well as for quality.

The only variable where significant differences were found by type of enterprise was in the importance of supports. Thus, credit support and technical assistance for modernization,

the cooperation fund for research, standardization and quality improvement, and services for searching for patents and technological information are more important for medium-sized companies than for small ones, while for microenterprises the problems they face in not using them are the high guarantees they demand.

In the function of assimilation and implementation of technological heritage (FIV), the involvement of SMEs with changes in products, engineering processes, production, and adaptation (at least eight out of ten) can be highlighted. 75% share with their staff these changes through various means such as practices, advice, consultancies, but more for training, while a quarter are not interested in making them known. The main source for orienting change is the market (customers and the marketing area), while the second is internal sources such as the engineering and the research and development areas, and the third is the specific (providers) and generic (Internet and the family) environment. At this point there are significant differences; being the customers important for all SMEs, they are even more so for small and micro enterprises. And another differentiating element for microenterprises is the transcendence of sources such as Internet and family. Finally, it can be noted that the depth of the changes has to do with the historical performance of the enterprise and not with a level of national or international competitiveness. A little more than a tenth is making competitive changes through the registration of patents and trademarks, as well as the signing of confidentiality contracts.

In terms of technological assets, seven out of ten SMEs value their technology on average while only ten out of one hundred consider it above average. This technology is rated by a little more than half of the respondents as in the maturity phase and a third in development, while in ascent just over 10%.

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Table 6.
Stage 4. Assimilation and implementation of technological heritage.

Modifies engineering, production, or equipment adaptation processes		**Makes changes or modifications to products**		**Ways to involve staff in changes %**		**Degree of novelty of the changes %**	
85.2%		80.2%		Practical training and workshops	58	Only for the enterprise	87.7
Sources of inspiration for adopting the changes %		**Important motivations for technological activities %**		Technical and advisory services	16	At an international level	7.4
✳ Customers	83.9	Improve the technical staff	64.7	**Impacts of the technology used in the company %**		At a national level	4.9
Marketing Area	70.4	Access to staff with other qualities	59.3	Increase in sales	64.2	**Status of acquired technology %**	
Internal R&D	69.1	Optimize processes	55.6	Capture new customers	61.7	New	85.2
Engineering area	66.7	✳ Export activity	43.2	Access regional markets	56.8	Used	14.8
Suppliers	66.7	**Performs technology transfer** 28.4 %		✳highly specific products	53.1	**Situation of the company in relation to technological activities %**	
✳ Internet	59.8	**Industrial Property %**		✳Superior quality development	49.3	Encourages collaboration	49.3
✳ family	44.3	Patents	9.9	✳ access the international market	44.4	Tracks technology	22.2
Situation of the technology in the company %		Confidentiality agreement	8.6	**With respect to the industry %**		Autonomous to obtain the technology	19.8
Maturity	54.3	Registered trademarks	7.4	Average	71.6	Leader in technology	8.6
Development	29.6	Utility models	4.9	Above average	19.8	**Reputation in relation to its technological activities %**	
Ascent	14.8			Below average	8.6	linkage or collaboration	55.6
Decline	1.2					✳ Innovation	54.3
						R&D in products	54.3
						Creation of its own technology	49.4

* Variables with a significant difference between enterprise sizes.

With regard to the impact obtained with the use of technology, more than half consider that the result has been an increase in sales, the capture of new customers, or the access to regional markets, with a little less orientation towards the external market; while an intermediate level of SMEs considers that the main effect is on the products, to provide them with specificity or quality. Rationality for technological development is related to human capital, either to improve or complement it or to improve processes, and a little less to promote export capacity. This development has a limited scope towards the enterprise itself, as only one third of the companies declare that they transfer or share the changes. As for the innovative strategy, less than a tenth is considered a leader, a fifth are autonomous, and 50% are dependent—as they are subordinated to their customers and suppliers to access technological innovations. Finally, what SMEs perceive that their stakeholders value most in their technological activities is their relational capital, the novelty and change in products, as well as their efforts to maintain their technology.

According to the ANOVA tests carried out, SMEs show differences in terms of rationality for technological development, in the impacts of the use of technology, and in their technological reputation. For small and medium enterprises, technological activity can be a determining factor in initiating or increasing export activity, while only for medium-sized enterprises can it be said that the technology used has had an impact on entering international markets. And a differentiating element is that only in medium-sized companies has the technology been able to impact on the development of highly specific products for specialized niches and products of superior quality in the industry. This can be corroborated in the reputation that is made in the market because the technological activity generates for medium-sized companies fame as innovators.

Patterns by size

Microenterprises classify supply channels and suppliers as the most important source of information for analyzing the environment. For them it is even more important to carry out a technical study before acquiring the technology, and they integrate R&D more into sales than into any other area. They are inspired by customers, internet, and family to make changes. They allocate a still low percentage of their sales to the purchase of new technology, they try to protect the changes they make and, although few apply for patents, they are usually recognized as innovative enterprises. The small enterprises carry out activities of analysis of the environment, establish the criteria for the evaluation and selection of the technology. They carry out research and development activities, assign personnel to these activities, occupy a high average percentage in the purchase of new technologies, and have had cooperation with other institutions to carry out research and development. They make changes and adjustments and protect their innovations. However, they are not completely recognized as innovative enterprises. Medium-sized enterprises have a faster behavior, they fulfill and carry out all the phases, activities, and characteristics of an efficient technology management: 1) analyze the environment; 2) investigate and evaluate the technology before acquiring it; 3) acquire the technology according to the specific needs to satisfy, make changes and adaptations; 4) implement their technology with the changes made in addition to protecting those changes. It should be noted that they allocate a medium-high percentage for research and development activities and for the purchase of new technology, as well as being perceived as innovative enterprises.

Patterns by size, sector, and location

The six clusters identified can give rise to specific patterns by size, sector, and location; their main characteristics are presented below:

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Table 7. Main Differentiators in Empirical Patterns of Technology Management.

Cluster	I/10 cases	II/5 cases	VI/40 cases	V/15 cases	III/2 cases	IV/9 cases
Size	Micro	Micro	Micro-small	Micro-small	Small-medium	Medium
Sector I		Construction		Manufacturing		Agroindustry
Sector II		Manufacturing	Manufacturing + Agroindustry		Construction	Manufacturing
Locality	Irapuato-Guanajuato	Celaya-León	Industrial Corridor	Celaya-Salamanca	León-Salamanca	Celaya-León
Planning	Biannual Annual	Biannual	Annual	Biannual Annual	Annual	Biannual
Generic environment	Economic Technologic	Economic	Technologic	Ecologic Economic Technologic		Economic Technologic
Relevant environment						Market** Partners**
Acquisition criteria	Technical study**	Technical study price**		Technical study**	Technical study**	Technical study**
R&D condition				Formal R&D		Formal R&D
R&D integration	Sales **	Sales **	Sales **	Without integration	Sales **	Sales**
R&D personnel level of education	Graduate	Graduate	Graduate	Graduate	Graduate	Post-graduate
Acquisition source	Suppliers	Suppliers	Suppliers	Employees Suppliers	Suppliers	Suppliers Change in the process
Impacts by Acquisition	Work costs	Change in the process	Change in the process Product Range			
Infrastructure	Maintenance workshop	Maintenance workshop	Maintenance workshop	Maintenance workshop Quality Lab	Quality Lab	Quality Lab
Sales and purchase of technology	20%	10%	10%	10%	20%	10-20%
Support	Modernization	Patents and technologic information **	Patents and technologic information **	Modernization	Modernization ** Quality**	Modernization ** Cooperation**
Communication with the personnel	Practices	Training	Training practices	Training practices	Training	Training
Intellectual Protection		Confidentiality Patents Trademarks	Utility model	Utility model	Confidentiality	Patents
Inspiration	Internet**	Internet- family**				
Technological Impact	Superior quality**	Specific products Superior quality**	Superior quality	Superior quality** Specific products	Superior quality**	Superior quality** Specific products** International markets**
Technological situation with respect to the industry	Maturity-average	Developing-average	Developing-average	Maturity-average	Maturity-below average	Maturity-above average
Technological Reputation	Follower-innovator	Follower-innovator	Follower	Autonomous-innovator	Moderately**	Autonomous-innovator

Where ** = statistically significant variable in Tukey's Test.

Microenterprises give rise to two characteristic patterns. Those that are located in Irapuato-Guanajuato (cluster 1, 12.5%), exclusively of construction, that are considered technologically mature acting in the average of the industry that carries out a more frequent technological planning, which puts greater reach in the environment by focusing on the economic and technological. They consider the main impact of the acquisition to be the reduction of labor costs and communicating changes to the personnel through practices. They allocate up to 20% to the purchase of technology and their main support is for technological modernization. The impact that stands regarding the implementation of technology management is the superior quality of their production. Meanwhile, those in Celaya-León (cluster 2, 6.3%), in construction and manufacturing, rate the technology in use as developing and that it also contributes to the average of their industry. In addition to considering the technical study, they rank price as the main criterion for technology selection. They identify the change in the productive process as the main impact of the acquisition. They only allocate up to 10% to the purchase of technology and the main support they request is for the search of patents and technological information. The mechanism to protect their technological heritage ranges from patents and confidentiality contracts to trademarks. Among its main sources of information besides the Internet are family members. Its technology management is aimed at developing highly specific products for its customers, as well as their superior quality.

Small enterprises have three empirical patterns of management (clusters 6, 5 and 3). The first two include micro enterprises, which are considered to be in a technological situation that is the average in their industry. Both communicate changes to their employees through practices and training. They secure their technological assets through utility model registries. The former, with micro enterprises (cluster 6, 49.4%), is present in all the municipalities studied in the industrial corridor and covers the three sectors analyzed. In their planning, they consider the technological environment. Their R&D is highly integrated with the sales function. Its acquisition impacts are distinguished by including the change in the process and the increase in the range of products. The required support is for the search for patents and technological information. They are qualified as technological followers. While the second pattern with micro enterprises (cluster 5, 18.5%), located in Celaya and Salamanca in the manufacturing sector, is one of the most complete when formalizing its R&D. They show frequent planning that includes diverse environments such as ecology. In addition to technology suppliers, they consider their employees an important source of acquisition. Their technology adaptation infrastructure includes maintenance workshops and quality laboratories. The main impact of the acquisition is productivity and product improvement. The most valued support is for technological modernization. They ensure that their management translates into superior quality and customer-oriented products, and they see themselves as independent technology followers and have a reputation for innovation. Finally, the third pattern (cluster 3, 2.5%) represents small and medium-sized companies that qualify below the industrial average and are located in León and Salamanca, both in manufacturing and construction. They place more emphasis on the relevant environment in its annual planning and evaluate the market predominantly with technical studies through their graduates who work in the sales area. They depend on their suppliers, training, and quality laboratories for their acquisition and technological adaptation, to which they apply up to 20% of their sales. They bet on protecting their technological assets through confidentiality and qualify them as mature, in addition to feeling perceived as moderately innovative by their stakeholders.

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In terms of cluster analysis, median enterprise size is an empirical pattern (cluster 4, 11.1%). It is located in agroindustry and manufacturing in the most developed municipalities of the State, Celaya and León. Their planning is half-yearly and includes the economic and technological environments. Their R&D is formalized and occupies postgraduate personnel. Not only do they require support for technological modernization, but also for cooperative research. They are protected by patents and declare that their management, in addition to being oriented to superior quality and customers, seeks to sustain the entry into international markets. The technological situation in their sectors and industry consider them mature and are referenced in the average. They declare technological autonomy and are considered innovators.

Discussion and conclusions

The basic activities for the function of the Analysis of the Environment of the MSMEs in our study are the realization of internal and external situational analysis, with annual base, considering the employees, customers, and suppliers, as well as the machinery and equipment favoring the information of the news of companies and the supply channels.

This function can be aligned with theoretical models to the extent that it accounts for systematic activities to capture information (both inside and outside the enterprise), it reveals the consideration of various stakeholders, and pays attention to the environment to seek opportunities and threats for technological modernization and innovation.

With respect to market research and technology evaluation, our evidence recognizes a trajectory of own development, where various technologies are assessed according to their degree of specialization and sophistication with criteria of technical study, price, and financial study. Research and development are a distributed competition with other areas and, in particular, it is mostly integrated with sales and maintenance, even though the production and quality departments are considered more important for the development of this activity.

This function reveals a certain capacity to identify, assess, and select technology with technical-economic criteria where different specialists of the company participate, but not necessarily to design strategies for optimal use of the technology to be acquired given the limited activity of R&D as established by the theoretical models of management.

In the function of technological acquisition and adaptation, the main source of acquisition is the suppliers. This activity accounts for between 10% and 20% of sales and this investment seeks to increase productivity, improve product quality, and make changes in processes. Adaptation requires changes in engineering, production or equipment processes, or product modifications, which are carried out mainly by graduates through self-financed projects that represent less than 1% of sales, which take advantage of the infrastructure of maintenance workshops and quality laboratories. In these activities they have also resorted to the support of public universities. What is most in demand is support for modernization, training, and quality.

The empirical function establishes an organized management of internal resources, with clear objectives that allow moving from the purchase to the operation with its own financing that empowers the implementation by the own personnel and, as is the case, using support in the environment to facilitate assimilation, but reveals a high dependence on suppliers and very few links. In the activities associated with the assimilation and implementation of technology, the scope of the novelty of the changes made is basically confined to the enterprise and is made known to operating personnel through training and practices. These changes are inspired by

customers and the marketing area, by production and R&D, suppliers, as well as Internet and family. They help to improve and access human capital, optimize processes, and, in the largest companies, even to detonate export. The impacts reflect on various indicators of competitiveness such as costs, sales, penetration, expansion, product development and quality, development of international markets, among others. Although it is considered that, on average, the industry uses mature technology, it can generate its own technological patrimony.

As far as their theoretical references are concerned, our cases show the capacity to generate minor innovations through adaptation to their specific needs. Different impacts are perceived by these activities in the technological, economic, and emotional spheres. A limited technological heritage is established with few but diverse safeguards, from patents, utility models, and trademarks to confidentiality agreements. Few enterprises participate in the transfer of their modifications and even some are not interested in making them known. Success is associated with maintaining technological suppliers, modifying products, and keeping oneself in the technological average of the industry. From the clusters, one can infer the best practice of technology management of SMEs in the industrial sector of the state of Guanajuato. It is worth mentioning that these are and what is intended to expose them is that they can have a strategic sense where entrepreneurs are identified within a cluster, compared with others, and propose a continuous improvement of this activity to generate and develop technological capabilities that sustain their results in the long term.

For Phase I of Environment Analysis, the instrument shows that the six clusters are very similar. The most limited clusters are microenterprise and construction clusters (C-1, C-2 and C-3) with some flaws in technological monitoring, environmental analysis, and identification of information sources. Cluster 4, made up of medium-sized enterprises (Celaya-León), and cluster 5, made up of a mixture of micro and small manufacturing enterprises (chemistry and textiles in Celaya-Salamanca), are the ones that reveal a better score in this phase.

Within phase II relating to Technology Research and Evaluation, cluster 1 of construction micro-enterprises in Irapuato-Guanajuato is the most deficient, particularly with respect to suppliers and the R&D area. The largest clusters, 3 (small and medium-sized enterprises in León-Salamanca) and 4 (medium-sized enterprises in Celaya-León), framed in the three sectors analyzed show the best result. As for phase III of Acquisition and Adaptation of Technology, cluster 6 (delocalized micro-small companies) and cluster 1 (micro-constructors) pay less attention to hiring personnel and infrastructure for R&D, which leads to poor performance in modifying processes, but mainly products, which are the most limited in this phase. Cluster 4 (medium-sized enterprises in Celaya-León) and cluster 3 (small and medium-sized enterprises in León-Salamanca) present the best fulfillment of the phase, highlighting greater investment in technological acquisition combined with technical assistance and technological modernization programs.

Finally, concerning phase IV of Assimilation and Implementation of the technology, the cluster with the least relative efficiency was that of micro and small offshore enterprises (cluster 6). They consider themselves to be technological followers and distinguish themselves by using utility models as a safeguard mechanism and focusing the impacts of technology introduction on increasing the range of products in a situation where they consider their technology to be in the process of development. However, if the rest of the clusters are considered, which use mature technology, the one with the most limited performance is that of micro construction enterprises, which are considered technological followers and whose

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rationality for introducing technology is to increase scale and reduce labor costs. On the other hand, the most sophisticated pattern was that of medium-sized enterprises (cluster 4). The scope of the novelty of its modifications reached the international level. The mechanism to safeguard innovations turned out to be patents. Despite using mature technology, they declared to be above their industry. The introduction of technology sought multiple purposes, from modifying processes and improving quality to increasing productivity. They see themselves as autonomous and prestigious innovators, allowing them to internationalize their production. These practices suggest that there is a technological improvement with the increase of scale, differences in complexity between sectors (being greater the one derived from manufacturing versus construction) and between locations (greater in cities of greater relative development such as León and Celaya), but also that there are differences in complexity between the same size segments presenting two patterns in each of the sizes considered. If innovation follows a complex dynamic from gradual and cumulative processes, then growth can be presumed based on an evolution of sophistication in technology management. According to Nooteboom (1994), SMEs can change size to overcome innovative weaknesses such as limited absorption capacity, poor availability of information, high turnover of qualified staff, lack of technological intelligence, and poor condition to assume risks.

As for the differences by size, sector, and locality, some interpretations as to empirical regularities can be made with which to distinguish certain patterns and advance to conform possible interrelations between clusters on the degree of sophistication and the potential change of size, that is, not only to stay with a static pattern on the size but based on the sophistication in technology management postulate a dynamic pattern to move from one size to another. As for the pattern of "complexity-increase in size" a probable trajectory can be drawn from the microenterprise with the simplest pattern of technology management to the medium-sized enterprise with the most complex management. According to the Environment Analysis function, the pattern becomes more complex and the enterprise grows due to the increase in frequency in the planning and complexity of the environment. With regard to market research and technological evaluation, the common practice is to carry out technical studies and integrate the R&D activity with the sales area. In the following function relating to technological Acquisition and Adaptation, the impacts experienced by companies range from labor costs to changes in processes, from the need for modernization support to access to technological information and back to technological modernization (circular pattern), and from here to quality improvement and sources of cooperation, while the support infrastructure is supported from a maintenance workshop to a quality laboratory. Finally, in the function of Assimilation and Implementation, intellectual property moves from confidentiality and trademarks to utility models and back to confidentiality (circular pattern), from where it advances towards patenting; and the technological impact goes through quality to reach specific products and end up in international markets. Thus, with this diversity of patterns it can be considered that the objectives of this research work were met. The current situation of technology management was described function by function, which revealed a strategic vision manifested in an orientation that allows the development of learning capacities—identify, assimilate, exploit knowledge of the environment, and (internal) resource management capacity—in a rational and appropriate way: capital, experience, and technology for innovation processes, although it falls short of other innovation capacities such as R&D, production, and linking capacities. With these descriptions, the elaborated proposition can be accepted. The SMEs in the industrial

sector of the state of Guanajuato perform some functions of technology management models with a strategic vision and thus verify, with the results of the survey, the various tests and statistical techniques that make up various empirical patterns of technology management according to their size, sector, and location that were tested by describing the groups obtained by cluster analysis. Although all the sizes of companies analyzed perform the basic functions of managing technology and their relevant environment qualifies them as innovative companies, there are significant differences between them. The factors that induce these differences—as the literature shows the development and growth of an enterprise and our research ratifies—are marked by the ability to access resources and their environment. However, our study makes it clear that these differences also exist due to technological sophistication. A situation that affects the desires and visions of businesspersons when they want to extend their technological heritage. Thus, technology management does not depend solely on the purchase of new and specialized technology as erroneously thought. Rather that the competitive difference lies in how efficiently they manage, administer, or direct the resources that they currently have to generate knowledge, research, and innovation, thus arriving at the development of the dynamic capacities of the enterprise.

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