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Relationship between total quality management (TQM) and technology R&D management (TM/R&D) in manufacturing companies in Mexico

La relación entre gestión de la calidad total (GCT) y gestión de la tecnología/I+D (GT/I+D) en empresas de manufactura en México

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Abstract

This paper explores the relationship between Total Quality Management (TQM) and the Technology Management along with R&D management (TM/R&D) to answer two central questions: whether TQM favors or limits the development of technological innovation capacity in Mexican organizations, and if the TQM can serve as support to the TM/R&D. The statistical significance of the theoretical model that relates TQM to TM/R&D is evident through the analysis of bivariate correlations, structural equations and multiple regression based on the survey of 125 manufacturing companies operating in Mexico.

The results indicate that there is a significant and positive correlation between TQM and TM/R&D. Among the facilitating elements, strategic alignment that amalgamates quality and technological innovation, customer focus, process management and the foundation offered by talent management processes are highlighted.

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Keywords: Total quality management; Technology management; R&D

Resumen

Este trabajo explora la relación entre Gestión de la Calidad Total (GCT) y Gestión de la Tecnología e I+D (GT/I+D) para responder a dos preguntas centrales: si la GCT favorece o limita el desarrollo de la capacidad de innovación tecnológica en las organizaciones mexicanas, y si la GCT puede servir de soporte a la GT/I+D. Se evidencia la significación estadística del modelo teórico que relaciona la GCT con la GT/I+D mediante el análisis de correlaciones bivariadas, ecuaciones estructurales y regresión múltiple a partir de la encuesta realizada a 125 empresas manufactureras que operan en México. Los resultados indican que existe una correlación significativa y positiva entre la GCT y la GT/I+D. Entre los elementos facilitadores destacan el alineamiento estratégico que amalgama calidad e innovación tecnológica, el enfoque al cliente, la gestión por procesos y el fundamento que ofrecen los procesos de gestión del talento.

Código JEL: L15, L69, O32
Palabras clave: Gestión de la calidad total; Gestión de la tecnología; I+D

Introduction

This article derives from a doctoral thesis (Ahuja, 2017) that seeks to provide knowledge in the field of management and administration regarding a complex, contemporary, and highly relevant phenomenon that has not yet been sufficiently studied in the Mexican context, referring to whether the principles and practices associated with Total Quality Management (TQM) limit or facilitate the innovation capacity of organizations (Flores, 2000; Hendrichs and Flores, 2001); and how TQM can serve as support for Technology Management and R&D (TM/R&D), specifically in the case of manufacturing companies (Agarwal, Green, Brown, Tan, and Randhawa, 2013; Yusr, Mohd, and Othman, 2014; Long, Abdul, Kowang, and Ismail, 2015).

The multidimensionality of both management models is well known (Singh and Smith, 2004; Prajogo and Sohal, 2006a and 2006b; Abrunhosa and Sá, 2008; Carlos and Silva, 2010; de Almeida, Severiano, and Tondolo, 2016). Quality and innovation are polysemic, relative and often subjective concepts (Cruz, 2001; Benavides and Quintana, 2003; Sila and Ebrahimpour, 2003; Hernández, Muñoz and Santos, 2006; Carlos and Silva, 2010). Total Quality Management (TQM) intervenes as an effective strategy to improve performance in for-profit and nonprofit organizations (Carlos and Silva, 2010; Mendoza, González, and Aquiahuatl, 2013); additionally, innovation and technology are key factors to raise the competitive level of organizations, regions, and countries (Rodríguez-Pose and Villarreal, 2015; Mir, Casadesús and Petnji, 2016; Palomo and Pedroza, 2018).

In the studies focused on analyzing the relationship between quality and innovation that have been published, contradictory arguments are presented on the positive or negative influence of quality on the development of innovation capacity, mainly in the factors of: customer focus, continuous improvement, teamwork and empowerment, and standardization and elimination of errors (Westphal, Gulati and Shortell, 1997; Cooper, 1998; Prajogo and Sohal 2001, 2003, 2004a and 2004b; Martínez and Martínez, 2008; Satish and Srinivasan, 2010).

It is observed that none of these studies have been carried out in the Latin American context, where the economic development and the evolution of TQM and TM/R&D show different conditions to those presented in the European or Asian countries in which they have been carried out.

On the other hand, the multidimensional nature of both quality and technological innovation has been taken into account, recognizing the complex nature of the connection between TQM and TM/R&D (Singh and Smith, 2004; Prajogo and Sohal 2004c, 2006a and 2006b; Abrunhosa and Sá, 2008; Carlos and Silva, 2010; de Almeida, Severiano and Tondolo, 2016; Palomo and Pedroza, 2018), which suggests that the available findings are insufficient to further clarify the nature of the relationship between the two management approaches, and their relationship should therefore continue to be studied.

Perdomo, González, and Galende (2009) consider that companies evolve starting from the formation of basic production capacities, then with the promotion and improvement of certain TQM practices, and then they move on to the development of complex innovation capacities.

It is evident that it is urgent to promote, in the Mexican productive sector, management approaches that incorporate practices oriented towards the following: the adaptability of the organization to the environment and the effective response to challenges; the elevation of labor productivity; the improvement of quality; and the development of innovation capacity. All of these will result in the competitive development and sustainability of organizations, which is important in terms of the relevance of the purposes of this paper, referring to the study of the relationship between total quality management and innovation.

The objectives presented for this study are:

- Examine the relationship between TQM and TM/R&D in manufacturing firms in Mexico, which can help reduce the gap between these two approaches that are often addressed separately in firms, as identified by Prajogo and Sohal (2006a).
- Identify the impact of TQM and TM/R&D on quality and innovation performance, measures that, according to various authors (Hoang, Igel and Laosirihongthong, 2006; Perdomo, González and Galende, 2006 and 2009; Prajogo and Sohal, 2006a;

Santos and Álvarez, 2008; Satish and Srinivasan, 2010; Palomo and Pedroza, 2018), have been considered the main sources of competitive advantage.

Literature review. Relationship between TQM and innovation

There is still no consensus on the positive or negative nature of the relationship between TQM and the development of innovation and, from theoretical and empirical perspectives (which have yielded divergent results), it seems to be a contradictory and complex relationship (Prajogo and Sohal, 2001; Singh and Smith, 2004; Perdomo, González, and Galende, 2006 and 2009).

For example, Maguire and Hagen (1999, cited in Prajogo and Sohal, 2003) consider that organizations should choose to focus on quality or innovation, as it would not be possible to succeed in applying both approaches simultaneously. However, this view does not seem to be generally accepted. For Kanji (1996, p. 5):

> *"[…] the main objective of both TQM and innovation is to 'delight customers with the help of continuous improvement', [...] which can be achieved through an evolutionary or revolutionary process using TQM principles. The crucial link between innovation and TQM is therefore, in the long and short term, the quality strategies that integrate today's action with tomorrow's vision".*

The international ISO 9004: 2009 guide has evolved from an approach focused on guidelines for improving the performance of the quality system to one in which quality management is part of a management model for the sustained success of organizations in a complex, demanding, and constantly changing environment, which involves generating and managing constant flows of improvement and innovation.

Some authors such as Belohlav (1993) and Reed, Lemak, and Montgomery (1996) argue that TQM, in focusing on providing the best products to meet customer needs, encompasses both the cost leadership and differentiation strategies of Porter's (2009) model. Others believe that differentiation is only achieved through innovation where the emphasis is on new product development (Porter, 1980; Miller, 1988; Abernathy and Utterback, 1988; Gobeli and Brown, 1994, cited in Prajogo and Sohal, 2001), while companies focused on quality pay more attention to process improvement with a preferential focus on cost leadership (Porter, 1980; Miller, 1988; Gobeli and Brown, 1994, cited in Prajogo and Sohal, 2001).

In contrast, Beinhocker and Kaplan (2002) argue that by instituting a TQM program as a major component in the strategic planning process, management achieves a new and creative approach to management, which in itself nurtures innovation, in addition to aligning quality with business objectives.

Zairi (1999, cited in Prajogo and Sohal, 2001), in his study on best practices in innovation management conducted in several "world-class" organizations (D2D, Rover Group, IBM (UK), 3M, Ford, ATyT, Cadillac, Hewlett Packard, Rank Xerox, Exxon Chemical, and Kodak), found that many of them are recognized as elements of TQM and include the application of principles such as "*quality culture*", "*learning organization*", "*customer-driven organization*", and "*continuous improvement*", using a wide variety of quality tools such as: quality function deployment (QFD), Taguchi methods, experiment design, statistical process control, mode and effect analysis of potential failures (AMEF), *poka-yoke* mechanisms, benchmarking, six sigma design, problem solving and planning tools, quality systems under ISO 9001 standards, delegation or empowerment, participation of employees and in multifunctional teams and supplier development.

Despite the foregoing, Zairi (Op. cit.) suggests that the majority of companies find great challenges in the implementation of the concepts and techniques of TQM in the area of innovation, while Chatterji and Davidson (2001) recognize that the initial efforts of companies (such as Xerox, 3M, Eastman Kodak, and other companies that are part of the Industrial Research Institute) to adapt and apply their principles in Research and Development (R&D) management have presented some subtle but far-reaching contributions:

- The importance of the understanding and fulfilling the needs and expectations of the customers, same which need to be reinforced in most R&D areas.
- The potential for continuous improvement for management practices and processes in R&D.
- The use of formal benchmarking, leading to better communication between workers in R&D from different industries, which speeds up the learning through non-traditional frontiers.
- The development of indicators that help identify the trend, development, and results of the R&D activities.

In Mexico, the National Technology and Innovation Award (PNTi[1] for its acronym in Spanish), based on the pioneering experiences of Spain and Portugal, base their model in the Technology Management Standards of the Mexican Standardization and Certification Institute (IMNC for its acronym in Spanish) (Ortiz, Pedroza and Samaniego, 2013; Medellín, 2010, 2013).

However, Pekovic and Galia (2009), based on the results of the study on the impact of quality systems under the standard ISO 9000 in 1,146 French manufacturing companies, consider that in several organizations the barriers to innovation are hard to overcome without the implementation of quality practices that help create an environment and a culture that favor innovation.

[1] For further information, consult the website of the National Technology and Innovation Award Foundation: http://fpnt.org.mx.

As can be observed, the theoretical and empirical studies on this topic point to different roads. There are those who consider that TQM has to be a driving force and an essential requirement to develop innovation in the company, and then there are those who believe that this relationship is negative and that TQM could hinder innovation.

In order to support the development of this work, nineteen empirical studies oriented towards the identification of the contribution of TQM in innovation development were carried out in Australia, South Korea, Spain, France, India, the Netherlands, Portugal, Singapore, Taiwan, and Vietnam; however, these are still insufficient, making it necessary to delve into the study of this relationship[2]. Departing from the analysis of these empirical studies, the following general findings regarding the relationship between TQM and innovation are identified (Ahuja, 2017):

- TQM, as a multidimensional management model, has practices with a mechanistic approach that are linked to quality performance, and practices with an organic approach related to innovation performance.
- Although TQM is a more efficient means to achieve results more oriented towards quality than towards innovation, it sometimes explicitly contributes to the latter, and most of the time implicitly, so it may be used along with TM/R&D to improve innovation performance.
- If the objective is to achieve a high innovation performance level, then it is necessary to have the capacity to fully manage quality requirements.
- The principles of TQM are efficient for the development of capacities in the areas of R&D, and they could also facilitate the standardization of the new products, processes, or services.
- TQM may provide an adequate environment to overcome possible barriers and increase the capacity for innovation of organizations due to its potential to develop changes in culture, if applied in a broad sense and not only the technical aspects.
- TQM must be complemented with other existing resources in the organization in order to efficiently support the continuing of a high-performance level in the entire spectrum of innovation practices.
- TQM allows the use of the capacities of the company through the development of incremental innovations and promotes the development of necessary skills for radical innovation.
- If TQM is aligned with other strategies, it could provide the foundation on which organizations can build their own technological skills and capacities to achieve a multidimensional competitive advantage that includes innovation, as well as the

[2] The comparative analysis of the main conclusions of the 19 empirical studies analyzed for this work can be found in Ahuja (2017).

capacity to adopt and absorb it within the company.

- A complex relationship between TQM and technological innovation (considered as innovation based on the industrial application of scientific and technological knowledge) is assumed. This requires continuous study to more specifically define the impact of each of the practices of TQM in innovation, as well as their link to TM/R&D in different contexts.

Despite these promising findings, it is recognized that the analyzed studies are still insufficient and, as mentioned before, the results show contradictory arguments concerning the nature of the relationship between TQM and innovation, mainly regarding the roles of customer focus, continuous improvement, teamwork, empowerment, and the focus on standardization and the elimination of failures[3].

Conceptual foundation of the proposed model

This study seeks to improve the understanding of the relationship between TQM and TM/R&D in the context of manufacturing companies in Mexico. This is done with the aim of helping reduce the breach between these two approaches that tend to come up separately in companies, as indicated by Prajogo and Sohal (2006a).

The introduction of the quality concept has come a long way to become a management model that has given successful results worldwide regarding the positioning of companies, and has become essential to remain in the market.

The conditions of the industry and markets, and the different burdens that have to be faced as a result of the changing rules of competition, cause a lot of organizations to concern themselves with the development of differential advantages sustained in innovation (Damanpour, 1996; Hoang e Igel, 2006; Pedroza, 2013).

Once the relationship between TQM and TM/R&D is established, TQM may offer a platform on which companies can develop the necessary basic skills for the development of innovation.

In the broad review of the literature for the development of this research, it was concluded that the concepts of quality and innovation are multidimensional and evidently polysemic, illustrating their relativity and subjectivity. This has an impact on the complexity of the management models that have been developed to achieve them.

The studies on TQM consulted for this research have been done parting from the principles and quality factors considered, be it the international ISO 9001 standards or the organizational direction models based on quality. These are also utilized for awards such as: *The Deming Prize* in Japan, the *Baldrige Performance Excellence Program* that is utilized in the United States of America, the *Modelo Nacional para la Competitividad* in Mexico, and the EFQM

[3] The specifics of these differences may be found in Ahuja (2017).

Excellence Model established in the European Union.

This study was based on six criteria of organizational practices associated with the aforementioned quality-based management systems and models: leadership, planning, customer focus, information and analysis, people management and process management that had previously been used by Samson and Terziovski (1997), and Prajogo and Sohal (2006a), who had assessed both their significance and their predictive power.

Concerning the organizational practices that make up TM/R&D, the variables that comprise technology management and research and development administration (Medellín, 2010, 2013; Ortiz and Pedroza, 2006) were taken into consideration. These comprise the basis of the criteria used to grant the PNTi in Mexico, taking into consideration that *"The composition of innovation projects requires preliminary work called research and development (R&D). At this stage, alternatives are explored, and business plans that can become innovations are prepared"* (Kato and Fernández. 2017: 29).

It is worth mentioning that in Mexico little is known about the effectiveness of investment in innovation in small and medium enterprises. One exception is the success cases awarded by the PNTi, which, since 1998, has recognized organizations that distinguish themselves by achieving competitive advantages through technology management (Medellín, 2010). Another initiative in this area are the six Mexican standards in NMX-GT4 technology management, based on the international criteria of the Oslo and Frascati manuals, so that companies have a technology management model and recognize and identify technology projects to promote innovation results.

The criterion used to measure technology management was based on Morita and Flynn (1997), whose model is characterized by adaptive behavior to technological processes and opportunities, including the search for cutting-edge technologies in industry, anticipating the potential of new technologies, implementing long-term programs for the development of technological capabilities, and constantly thinking about the next generation of technology.

As Velasco, Zamanillo, and Gurutze (2007) conclude in their analysis of the evolution of the models on the innovation process, a good part of the technological knowledge of the company is in the R&D department. It is therefore necessary to include it in the analysis model, taking into consideration the variables that make up the technological innovation audit model of Chiesa, Coughlan, and Voss (1996), and those used in their studies by Gupta, Wilemon, and Atuahene-Gima (2000), and Prajogo and Sohal (2006a).

In order to measure the performance in terms of quality of products and services, the variables developed by Ahire, Golhar, and Waller (1996) were taken into consideration, containing four dimensions: reliability, performance, durability, and conformity to specification.

[4] For more information visit the website of the Mexican Standardization and Certification Institute: http://www.imnc.org.mx.

Finally, to measure the results in terms of product innovation and process innovation, criteria were used such as the number of innovations, the speed of innovation, the level of innovation (novelty of the technological aspect), and "being first" in the market according to the Oslo Manual (OECD/Eurostat, 2005).

As can be seen in Figure 1, the model seeks to investigate the relationship of TQM and TM/R&D as organizational resources to determine quality performance and innovation performance.

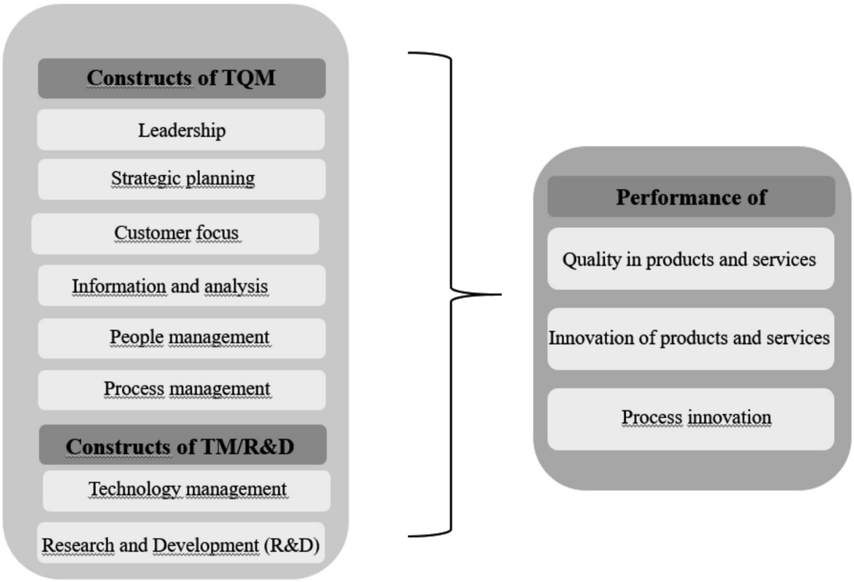

Figure 1. Conceptual model proposed.
Source: Author's own based on Prajogo and Sohal (2006a).

The approach was analytical-deductive in order to confirm, in the Mexican manufacturing context, the relationship between the main constructs that comprise the Total Quality Management (TQM) and those that comprise Technology Management/R&D (TM/R&D), as well as its effect on results, both in terms of quality of products and services, product or service innovation, and process innovation.

The central working hypothesis is to confirm the relationship between six constructs that comprise Total Quality Management (TQM) and the two constructs that comprise Technology Management /R&D (TM R&D) and the performance reflected by the companies surveyed in terms of quality results and innovation results, as well as whether this result is improved by integrating TQM with TM/R&D.

Statistical instruments and methods used

A questionnaire based on the one used by Prajogo and Sohal was utilized as a tool to obtain information (2006a)[5]. It was integrated by the six main elements that comprise TQM, two of the main elements that comprise TM (with five items) and R&D (with four items), and three performance measures in this area: Quality and innovation of products and services, and process innovation (Figure 1). For its application in this research, the following modifications were made, in addition to those derived from the translation from English to Spanish[6]:

- In the management construct of people within the scope of TQM, a variable was added concerning the stimulus to collaboration and teamwork based on the following reasons:
  - Teamwork is one of the factors of quality practices (derived from work in continuous improvement groups or similar), which are controversial in the literature.
  - Teamwork skills are considered the most important among what companies in Mexico look for in candidates. This has been indicated both by personnel in the human resources area and by managers of the different areas. It is also the scarcest among young people seeking employment, according to the 2014 Professional Skills Survey: *What do companies look for -and do not find- in young professionals?*
- In the TM/R&D constructs, the variable that Prajogo and Sohal defined as the search for long-range programs to acquire technological capabilities to fulfill the needs of this study was translated into two complementary items: the monitoring of emerging technologies and the plans for the acquisition of technological capabilities to solve said needs.

The questionnaire was comprised of a total of 52 items (see Table 1) distributed in six constructs that measure the practices related to TQM, two constructs that measure the practices of TM/R&D, and three constructs that measure three different types of performance: quality and innovation of products and services, and process innovation, in which all the variables were measured through a 5-point Likert scale (Figure 1).

The validation of the modified version of the instrument was carried out by five experts in the field of quality management, innovation and technology management, and human resources, as well as through a pilot test in five companies that are not part of the database for this study.

[5] Prajogo and Sohal (2006a) report that the Goodness of Fit Index (GFI) of the eleven constructs of this instrument exceeded the 0.9 criterion suggested by Kelloway (1998), thus establishing the validity of the construct. The reliability analysis was performed by calculating Cronbach's Alpha for each scale. The result showed that the Cronbach's Alpha measurements for the eleven constructs exceed the threshold of 0.7 suggested by Nunnally (1978).

[6] The instrument used can be consulted in Ahuja (2017).

The estimation of the means and variances and the statistical analyses of the reliability of the survey were also carried out, determining the capacity of each of the constructs to measure what is intended, thus validating the internal consistency of the questionnaire (Saunders, Lewis, and Thornhill, 2009; Namakforoosh, 2011).

The eleven constructs that make up the instrument were subjected to the Cronbach's Alpha coefficient reliability test using a single score; the relevance of each of the items that comprise each construct was also evaluated by measuring Cronbach's Alpha after excluding each item and, in none of the cases did the suppression of any one significantly alter the Cronbach's Alpha of each construct with all its variables.

Table 1
Cronbach's Alpha reliability coefficient

	No. of Items	Mean	Variance	Cronbach's Alpha
Leadership	4	4.194	0.849	0.747
Strategic planning	4	4.094	1.069	0.837
Customer focus	6	4.208	0.793	0.787
Information and analysis	4	3.77	1.221	0.825
People management	6	3.756	1.216	0.921
Process management	6	4.012	1.088	0.821
Technology management	5	3.997	1.102	0.905
Research and Development (R&D)	4	3.706	1.526	0.912
Quality in products and services	4	4.338	0.627	0.856
Innovation of products and services	5	3.773	1.328	0.848
Process innovation	4	3.728	1.061	0.879
TOTAL	52			

Source: Author's own

As can be observed in Table 1, the results show that the Cronbach's Alpha measurements for the eleven constructs have values higher than 0.7, which places them at an acceptable level of reliability. The constructs: people management (0.921), technology management (0.905), and R&D administration (0.912) stand out as the three most reliable constructs on the scale, as they are the ones that come closest to the maximum value (1), while customer focus (0.787) and leadership (0.747) are the constructs with the least reliability on the scale, even if they are at an acceptable level.

For the correlation or degree of association test between the variables of the model used for this study, Spearman's Correlation Coefficient, which is used for ordinal variables (Martínez *et al*., 2009, p. 8), was utilized.

In order to estimate the effects and the relationships between the variables of the model (Ruiz, Pardo, and San Marín, 2010), the Structural Equation Models (SEM) analysis was used, considering that *"the true value of this technique is to specify the complex relationships between a priori variables, and then to evaluate how many of these relationships are represented in the empirically collected data"* (Weston and Gore, 2006, cited in Cupani, 2012, p. 188).

The results of the application of the survey were processed with Microsoft Excel 2016 for the descriptive statistical analysis, IBM SPSS Statistics 24 for the inferential analysis and IBM SPSS AMOS version 24 for the analysis of structural equations.

Results and discussion

The study was carried out in manufacturing companies in the 32 states registered in the National Register of Scientific and Technological Research Institutions (RENIECYT for its acronym in Spanish)7, which had 2,105 registered manufacturing companies at the time of access for this study.

From the registered companies, it was necessary to research the contact data through the Mexican Business Information System (SIEM for its acronym in Spanish), the National Statistical Directory of Economic Units (DENUE for its acronym in Spanish), and through Internet, obtaining 125 valid responses.

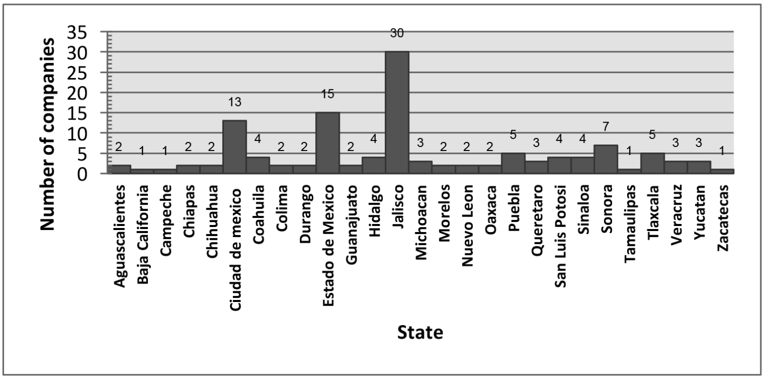

Figure 2. Companies surveyed by state.

Source: Author's own.

Figure 2 presents the geographical location of the companies that participated in the study.

[7] Institutions, centers, organizations, companies, and individuals or corporations from the public, social, and private sectors that carry out activities related to the research and development of science and technology in Mexico voluntarily register in RENIECYT. This means that they carry out scientific and technological research, technological development and innovation, as well as production of basic engineering.

The highest number of companies that answered were in the state of Jalisco (30), followed by those in the State of Mexico (15) and in Mexico City (13).

The structure of the sample by size and sector is presented in Table 2, where it is observed that the sample has a representation of all sizes and from the three sectors in which the manufacturing companies are grouped in this database.

Table 2

Surveyed companies by size and sector

Economic sector	Big	Medium	Small	Micro
Wood, paper, oil derivatives, and chemical industries.	7	13	14	7
Food, tobacco, beverages, and textile manufacturing industries.	3	11	9	5
Machinery and equipment manufacturing industry.	8	12	23	13
Total	18	36	46	25

Source: Author's own.

Concerning the profile of people who answered the survey, as observed in Table 3, the highest number of people work in the quality area (44%), followed by those who work in operations (16.8%), and then those in other areas of the company such as administration, commercial, human resources, etc. (16.8%).

It should be mentioned that 100 out of the 125 respondents have a directive or management position, identified based on the name of the position.

Table 3

Area of affiliation of the respondents

Area of affiliation of those surveyed	No. of respondents
R&D or innovation	11
Quality	55
Operations	21
Director or general manager	17
Other areas	21
TOTAL	125

Source: Author's own.

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Analysis of bivariate correlations

The decision was made to calculate Spearman's correlation for the analysis of correlations or degree of association between the variables of the model used for this study.

As can be observed in Table 4, all the constructs that comprise the proposed model have a significant relationship between them, including those that comprise TQM, those that form part of TM/R&D, and those that measure results in terms of performance, quality, and innovation of products and services, as well as process innovation.

Table 4

Spearman's correlation matrix.

		TQM						TM/R&D		PERFORMANCE		
		Leadership	Planning	Customer	Information	People	Process	Technology	R&D	Qual prod-serv	Innov prod-serv	Innov proc
TQM	Leadership	1.000	.708**	.619**	.612**	.732**	.567**	.495**	.488**	.391**	.409**	.469**
	Plannig	.708**	1.000	.666**	.768**	.768**	.754**	.529**	.473**	.508**	.352**	.419**
	Customer	.619**	.666**	1.000	.704**	.716**	.742**	.578**	.539**	.509**	.441**	.489**
	Information	.612**	.768**	.704**	1.000	.756**	.831**	.516**	.487**	.446**	.315**	.395**
	People	.732**	.768**	.716**	.756**	1.000	.781**	.577**	.563**	.565**	.441**	.546**
	Process	.567**	.754**	.742**	.831**	.781**	1.000	.553**	.510**	.473**	.327**	.413**
TM/R&D	Technology	.495**	.529**	.578**	.516**	.577**	.553**	1.000	.680**	.504**	.563**	.654**
	R&D	.488**	.473**	.539**	.487**	.563**	.510**	.680**	1.000	.402**	.615**	.639**
PERFORM	Qual prod-serv	.391**	.508**	.509**	.446**	.565**	.473**	.504**	.402**	1.000	.527**	.536**
	Innov prod-serv	.409**	.352**	.441**	.315**	.441**	.327**	.563**	.615**	.527**	1.000	.747**
	Innov proc	.469**	.419**	.489**	.395**	.546**	.413**	.654**	.639**	.536**	.747**	1.000

** The correlation is significant at the 0.01 level (bilateral).

Source: Author's own

The following stand out with the highest Rho coefficients: the people management with respect to technology management; R&D administration; performance in terms of quality of products and services and performance in process innovation; the focus on the customer; and the management of processes with the management of technology.

Structural equation model

A Structural Equation Model (SEM) has been developed as part of the quantitative approach of this study. For this work a confirmatory modelling strategy has been followed (Cupani, 2012), which will help to identify the relationship between TQM and TM/R&D and its impact on the results in terms of quality, product or service innovation, and process innovation.

Interest lies in the confirmation, through the analysis of the results derived from the sample under study, of the relationships proposed in the model itself based on the explanatory theory that has been used as a reference throughout this work (Figure 1); that is, it will allow contrasting whether the theoretical model with which this research has been worked corresponds

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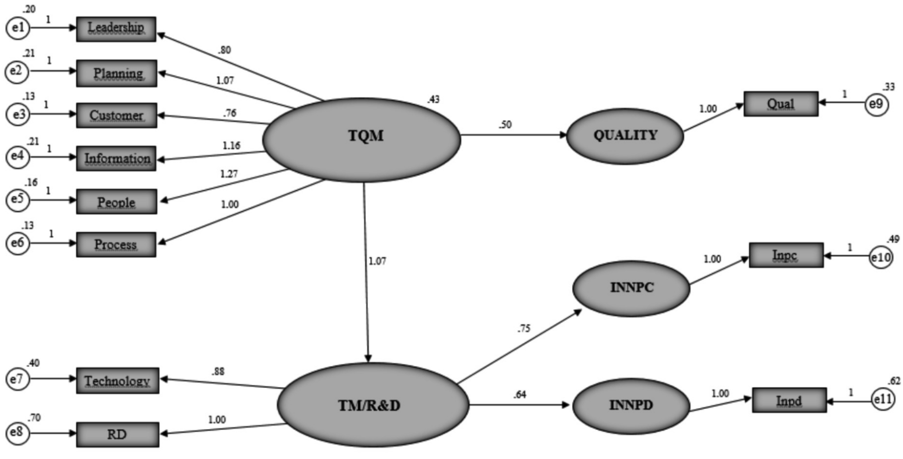
with the results obtained empirically from the survey carried out, and evaluate its statistical significance (Cupani, 2012). For a better understanding of the model, the meaning of its main components are indicated below (Lara, 2014; Arburckle, 2016).

The ovals represent the latent variables, and the boxes represent the constructs that encompass the observed variables, which together make up the instrument that was applied to the sample. The unidirectional arrows represent the lines of influence of the constructs on the respective latent variables and the numbers above these indicate the coefficient of the construct in the regression equation, that is, the weight or estimated contribution of each variable included in the regression model, which may be positive or negative. When bi-directional arrows are used, they represent the covariances (which were not used in this case). The circles represent the random error inherent in the measurement of each observed variable. The variables corresponding to the (non-observable) errors are represented with an oval or circle of a size smaller than that of the latent variables.

As mentioned above, the central purpose is to establish a model that makes theoretical sense in correspondence to the supporting literature, and a reasonable correspondence with the empirical data derived from the application of the survey.



$\chi 2 = 207.428$ g. l. = 44 p-value = 0.000 CFI = 0.837 GFI = 0.720

Figure 3. Structural equation model

Source: Author's own.

Figure 3 shows the values of the goodness-of-fit indicators that show that the proposed model has a reasonably good fit and is therefore acceptable.

As can be seen, the six constructs selected as part of TQM have considerable explanatory power in the model, highlighting the constructs people management (1.27) and information and analysis (1.16) as the most important variables. On the other hand, it can be observed that the two constructs that comprise the TM/R&D have a high level of relative weight (0.88 and 1).

The result of the confirmation of the proposed model indicates that the TQM has a significant and positive correlation with the TM/R&D. Also, the weight of TQM in the TM/R&D regression model is of 1.07, which indicates that TQM can support TM/R&D.

The next step was to broaden the appreciation of the impact of the results in terms of quality and innovation of products and services, and also in process innovation, once it is assumed that TQM can be a platform that supports TM/R&D, since in the analysis of bivariate correlations the integral constructs of each management approach had been considered independently. This confirmation was made through various regression analyses (Table 5) that gave statistically significant results, where it can be observed how, in all cases, the correlation coefficient (R) improves, this being the most significant improvement of the performance in process innovation, which goes from 0.568 to 0.698.

Table 5
Multiple regression analysis for TQM-TM/R&D

Independent variables	Dependent variables											
	Quality in products and services				Innovation of products and services				Process innovation			
	R	R^2	Adj. R^2	F	R	R^2	Adj. R^2	F	R	R^2	Adj. R^2	F
TQM	0.482	0.233	0.194	5.956***	0.461	0.212	0.172	5.32***	0.568	0.321	0.287	9.332***
TQM-TM/R&D	0.523	0.274	0.224	5.462***	0.63	0.396	0.355	9.519***	0.698	0.487	0.452	13.748***

*** Significant with $p < 0.0001$

Source: Author’s own

Similarly, the contribution of TQM-TM/R&D integration can be easily verified, highlighting the case of process innovation, where 32.1% (R2) of its variation is explained by the regression model containing the six TQM constructs. This percentage reaches 48.7% when the two TM/R&D constructs are included in the model in addition to the six TQM constructs.

Thus, the verification of the hypothesis of the relationship between TQM and TM/R&D and its impact on quality and innovation results is carried out according to the results obtained in the analysis of the proposed model, using the method of structural equations and multiple regression analysis.

As can be observed, derived from the quantitative study, it is confirmed that the theoretical model that has accompanied this research is consistent with the data obtained from the sample derived from the application of the questionnaire in 125 manufacturing companies operating in Mexico.

Likewise, it is verified, for this sample, that the constructs that integrate TQM present correlation with the three performance measures: quality of products and services, innovation of products and services, and innovation of processes, with this correlation being significant and positive. The observation of the consistent increase of this correlation when the constructs that integrate TQM and TM/R&D are used in a combined way is particularly interesting. This makes it possible to consider that the first one can serve as support to the second one.

The results indicate that both the six constructs of TQM and the two of TM/R&D have a greater degree of association towards process innovation than towards product and service innovation.

One aspect to consider is that both TQM and TM/R&D are multidimensional management models, which means that the relationship between them is not simple or linear, but rather complex. This indicates that it is necessary to give continuity to this research, integrating a qualitative approach that allows investigating how TQM can positively or negatively influence the development of innovation and how it can become a platform on which to develop capacities for innovation, in the case of Mexican companies.

Conclusions

This research increases the understanding of the current relationship between TQM and TM/R&D for the case of manufacturing companies operating in Mexican territory, where the characteristics of the cultural and socioeconomic environment make it particularly different from those of Asian or European countries where the published studies have been carried out, and which have been reviewed for this work.

The main findings derived from checking the statistical significance of the theoretical model that has been used as a reference in this work, concerning the results obtained empirically from the responses of the 125 manufacturing companies that participated in the study, are as follows:

- The analysis of applied structural equations has shown that there is a significant and positive correlation between TQM and TM/R&D, where the former has a significant weight in the regression that explains the latter.
- The results of the multiple regression analysis (Table 5) indicate that there is an impact on quality performance and innovation resulting from the synergy between TQM and TM/R&D.
- There is a significant and direct correlation between the six constructs of TQM and the two constructs of TM/R&D; although the strength of the correlation is not the same in all cases, the majority of the correlation is moderate (Rho coefficient between 0.516 and 0.578), with the highest correlation coefficients being people

management and customer focus with respect to both technology management and R&D administration, and process management with respect to technology management (Table 4).

In light of these findings, it is considered that the main contribution of this research has been to confirm, for the Mexican case and for the companies studied, firstly that TQM can be implemented in an integrated manner with the TM/R&D and, secondly, that the synergy between TQM and TM/R&D produces greater explanatory power in terms of the three performance measures studied (product quality, product innovation, and process innovation) than TQM alone, as discovered by Prajogo and Sohal (2006a).

In short, the results indicate that it is possible to develop capacities for innovation from the platform offered by the principles and practices of TQM associated with the six constructs studied, being necessary to ensure a proper integration of both management approaches and not just a simultaneous application; the variables of people management, customer focus, and management by processes stand out as the ones that can best constitute important resources for the development of innovation capacity in organizations.

This study can be useful for managers of manufacturing companies in Mexico interested in improving the performance of the organization in terms of quality and innovation with the help of the main practices of TQM, even though it is recognized, as was identified in the literature review, that few companies have managed to apply the concepts and techniques of TQM in the field of innovation and not many have managed to take advantage of the potential benefits of this management model if it is developed under a broader vision of it.

Taking into consideration the multidimensionality of both management approaches and the complexity of the relationship between TQM and TM/R&D, as well as in order to provide continuity and complement this research, a qualitative study has been developed whose methodology and results will be reported in a future article.

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Referencias

Abrunhosa, A. y Sá, P. (2008). Are TQM principles supporting innovation in the Portuguese footwear industry? *Technovation*, 28(4) 208-221. DOI: 10.1016 / j.technovation.2007.08.001.

Agarwal, R., Green, R., Brown, P. J., Tan, H., y Randhawa, K. (2013). Determinants of quality management practices: an empirical study of New Zealand manufacturing firms. *International Journal of Production Economics*, 142(1) 130-145. https://doi.org/10.1016/j.ijpe.2012.09.024.

Ahire, S. L., Golhar, D. Y. y Waller, M. W. (1996). Development and validation of TQM implementation constructs. *Decision Sciences*, 27(1) 23-56. https://doi.org/doi:10.1111/j.1540-5915.1996.tb00842.x

Ahuja, L. (2017). *El papel que juegan las prácticas asociadas a la Gestión de la Calidad Total en el desarrollo de la capacidad de innovación en empresas manufactureras ubicadas en territorio mexicano*. Tesis doctoral, Barcelona, España: Universitat Ramón Llull.

Arbuckle, J. (2016). IBM SPSS Amos 24. *User's Guide*. Amos Development Corporation.

Beinhocker, E. y Kaplan, S. (2002). Tired of Strategic Planning? *The McKinsey Quarterly,* Special Edition on Strategy, 48-57. Disponible en: https://www.mckinsey.com/business-functions/strategy-and-corporate-finance/our-insights/tired-of-strategic-planning# Consultado: 19/02/2018

Belohlav, J. (1993). Quality, Strategy, and Competitiveness. *California Management Review*. Vol 35(3) 55 – 67, First Published April 1, 1993. https://doi.org/10.2307/41166743.

Benavides, C.A. y Quintana, C., (2003). *Gestión del conocimiento y calidad total*. Madrid, España: Díaz de Santos.

Camisón, C., Boronat, M., Villar, A., y Puig, A. (2009). Sistemas de gestión de la calidad y desempeño: importancia de las prácticas de gestión del conocimiento y de I+D. *Revista Europea de Dirección y Economía de la Empresa*, 18 (1), 123-134 Disponible en: http://repositori.uji.es/xmlui/handle/10234/33356 Consultado: 19/02/2018

Carlos, C. E. y Silva, M. de los Á. (2010). *La Gestión de la Calidad. Un enfoque de Investigación*. México: Instituto Tecnológico de Aguascalientes.

Chatterji, D. y Davidson, J.M. (2001). One Point of View: Examining TQM's Legacies for R&D. Research-Technology Management, 44(1), 10-12. https://doi.org/10.1080/08956308.2001.11671400

Chiesa, V., Coughlan, P., y Voss C. A. (1996) Development of a technical innovation audit. *Journal of Product Innovation*, 1996; 13(2) 105–36. https://doi.org/10.1111/1540-5885.1320105.

Cooper, J. R. (1998). A multidimensional approach to the adoption of innovation. *Management Decision*, 36 (8) 493-502. https://doi.org/10.1108/00251749810232565.

Cruz, S. (2001). *Relación entre el enfoque de gestión de la calidad y el desempeño organizativo. Una aproximación desde la perspectiva basada en los recursos*. Tesis doctoral, Universitat D' Valencia. Disponible en: http://www.tesisenred.net/handle/10803/9663 Consultado: 19/02/2018

Cupani, M. (2012). Análisis de Ecuaciones Estructurales: conceptos, etapas de desarrollo y un ejemplo de aplicación. *Revista Tesis* (1) 186-199. http://dx.doi.org/10.4067/S0718-24492016000100004

Damanpour, F., (1996). Organizational complexity and innovation: Developing and testing multiple contingency models. *Management Science*, 42 (5) 693–715. https://doi.org/10.1287/mnsc.42.5.693

de Almeida, R. M., Severiano, C., y Gonçalves, V. A. (2016). Sobre a lógica das relações entre TQM e inovação: insights e proposições teóricas. *Revista Electrónica de Estrategia y Negocios*, 8 (3), 3-30. http://dx.doi.org/10.19177/reen.v8e320153-30

Ettlie, J. E. (1997). Quality, technology, and global manufacturing. *Production and Operations Management*, 6 (2), 150-166. https://doi.org/10.1111/j.1937-5956.1997.tb00423.x

Fisher J., Kirk C. y Taylor D. B. (1995). The implications of TQM for R&D strategy in New Zealand firms. *Technovation* 15 (1), 1–9. https://doi.org/10.1016/0166-4972(95)96607-U

Flores, K. (2000). *Análisis del Desempeño en Innovación de PYME's Participantes en el Premio Nuevo León a la Calidad mediante el Modelo Europeo para la Excelencia de Negocio enfocado a la Innovación*. Tesis Maestría, ITESM, Monterrey, N. L., México.

Gupta, A. K., Wilemon, D. y Atuahene-Gima, K. (2000). Excelling in R&D. *RyD Management* 43(3) 52–58. https://doi.org/10.1080/08956308.2000.11671358.

Hendrichs, N. J. y Flores, K. (2001). ¿La calidad obstaculiza la innovación? *Transferencia Revista Digital de Postgrado, Investigación y Extensión del Campus de Monterrey,* (54) 26-27. https://repositorio.itesm.mx/ortec/handle/11285/572823.

Hernández, R. M., Muñoz, P. A. y Santos, L. (2006). Calidad objetiva y su relación con la formación y la satisfacción del empresario: El caso de los alojamientos rurales españoles. *Programa de doctorado interuniversitario:*

Nuevas tendencias en dirección de empresas, documento de trabajo 13/06. España: Universidad de Valladolid. https://gredos.usal.es/jspui/handle/10366/75238.

Hoang, D.T., Igel, B. y Laosirihongthong, T. (2006). The impact of total quality management on innovation: findings from a developing country. International Journal of Quality and Reliability Management. 23 (9) 1092–1117. https://doi.org/10.1108/02656710610704230.

Honarpour, A., Jusoh, A., y Md Nor, K. (2018). Total quality management, knowledge management, and innovation: an empirical study in R&D units. Total Quality Management & Business Excellence, 29 (7-8), 798-816. https://doi.org/10.1080/14783363.2016.1238760

Jayawarna, D., y Holt, R. (2009). Knowledge and quality management: An R&D perspective. Technovation, 29 (11), 775-785. https://doi.org/10.1016/j.technovation.2009.04.004

Kanji, G.K. (1996). Can total quality management help innovation? *Total Quality management*, 7(1)3-10. https://doi.org/10.1080/09544129650035007

Kato, E. L. y Fernández, M. L. (2017). La productividad de las pequeñas empresas al innovar. Nthe (18) 29-34. Disponible en: https://www.academia.edu/37170137/CONCYTEQ.pdf Consultado: 19/02/2018.

Kelloway, E. K. (1998). *Using LISREL for structural equation modelling: a researcher's guide*. Thousand Oaks, CA: Sage.

Kumar, V., y Boyle, T. (2001). A quality management implementation framework for manufacturing-based R&D environments. *International Journal of Quality & Reliability Management*, 18 (3), 336-359. https://doi.org/10.1108/02656710110383557

ISO 9004:2009. *Gestión para el éxito sostenido de una organización - Enfoque de gestión de la calidad*. Ginebra, Suiza: Secretaría Central de ISO.

Kuruppuarachchi, D., y Perera, H. S. C. (2010). Impact of TQM and technology management on operations performance. *IUP Journal of Operations Management*, 9 (3) 23-47. Disponible en: https://search.proquest.com/docview/749648102/ Consultado: 19/02/2018.

Lara, A. (2014). *Introducción a las Ecuaciones Estructurales en AMOS y R*. Universidad de Granada. Disponible en: http://masteres.ugr.es/moea/pages/curso201314/tfm1314/tfm-septiembre1314/memoriamasterantonio_lara_hormigo/. Consultado: 19/02/2018

Long, C. S., Abdul, M. H., Kowang, T. O., y Ismail, W. K. W. (2015). Impact of TQM practices on innovation performance among manufacturing companies in Malaysia. *South African Journal of Industrial Engineering,* 26(1), 75-85. http://ref.scielo.org/w64dfy.

Manual de Oslo 3ª edición, 2005. *Guía para la recogida e interpretación de datos sobre innovación. OECD/European Communities*. Traducción española: Grupo Tragsa. Disponible en: https://www.oecd-ilibrary.org/science-and-technology/manual-de-oslo_9789264065659-es Consultado: 19/02/2018

Martínez, M. y Martínez, A. (2008). Does quality management foster or hinder innovation? An empirical study of Spanish companies. *Total Quality Management y Business Excellence*, 19 (3) 209-221. http://dx.doi.org/10.1080/14783360701600639.

Martínez, R.M., Tuya, L., Martínez, M., Pérez, A. y Cánovas, A.M. (2009). El coeficiente de correlación de los rangos de Spearman. Caracterización. *Revista Habanera de Ciencias Médicas*, 8(2), abril-junio 2009. Disponible en: http://scielo.sld.cu/scielo.php?script=sci_arttext&pid=S1729-519X2009000200017&lng=es&nrm=iso Consultado: 19/02/2018

Medellín, E. A. (2010). Gestión tecnológica en empresas innovadoras mexicanas. *RAI-Revista de Administração e Inovação*, 7(3) 58-78. Disponible en: https://www.revistas.usp.br/rai/article/view/79181 Consultado: 19/02/2018

Medellín, E. (2013). Construir la Innovación. México: Siglo XXI Editores y Fundación Educación Superior - Empresa.

Mendoza, V., González, B. P., y Aquiahuatl, E. C. (2013). Human approach in the quality management system of manufacturing SMEs in Mexico. Theoretical review and proposal of a conceptual model. *Contaduría y Administración*, 58(2)113-133. https://doi.org/10.1016/S0186-1042(13)71212-9

Mir, M., Casadesús, M., y Petnji, L. H. (2016). The impact of standardized innovation management systems on innovation capability and business performance: An empirical study. *Journal of Engineering and Technology Management*, 41, 26-44. https://doi.org/10.1016/j.jengtecman.2016.06.002.

Morita, M. y Flynn, E. J. (1997). The linkage among management systems, practices and behavior in successful manufacturing strategy. *International Journal of Operations y Productions Management;* 17(10):967–93. https://doi.org/10.1108/01443579710176933

Namakforoosh, M.N. (2011). *Metodología de la Investigación*. *México*: Limusa.

Nunnally, J. (1978) *Psychometric theory*. New York: McGraw-Hill.

Ortiz, S. y Pedroza, A. R. (2006). ¿Qué es la Gestión de la Innovación y la Tecnología (GInnT)? *Journal of Technology Management & Innovation,* 1 (2), 64-82. Disponible en: https://www.jotmi.org/index.php/GT/article/viewFile/rev1/327 Consultado: 19/02/2018

Ortiz, S., Pedroza, A. R. y Samaniego, A. (2013) Análisis Exploratorio del Sistema de Gestión de la Tecnología, Según la Norma Mexicana NMX-GT-003-IMNC. XV Seminario Latino-Iberoamericano de Gestión Tecnológica, ALTEC 2013, Porto, Portugal. Noviembre.

Palm, K., Lilja, J., y Wiklund, H. (2016). The challenge of integrating innovation and quality management practice. *Total Quality Management & Business Excellence*, 27 (1-2), 34-47. https://doi.org/10.1080/14783363.2014.939841

Palomo, M. A., y Pedroza, A. R. (2018). La competitividad empresarial: el desarrollo tecnológico. México, Universidad Autónoma de Nuevo León - ACACIA.

Pearson A.W., Vaughan N., y Butler J. (1998). The implementation of TQM in R&D. *International Journal of Technology Management,* 16 (4–6), 405–32. https://doi.org/10.1504/IJTM.1998.002679

Pedroza, A. R. (2013). Innovación y tecnología en la empresa. Claves para adelantarse al futuro. Guadalajara, México, Instituto Tecnológico de Estudios Superiores de Occidente.

Pekovic, S y Galia, F. (2009). From quality to innovation: Evidence from two French Employer Surveys. *Technovation*, 29 (12), 829-842. https://doi.org/10.1016/j.technovation.2009.08.002.

Perdomo, J., González, J. y Galende, J. (2006). Total quality management as a forerunner of business innovation capability. Technovation, 26, 1170-1185.
https://doi.org/10.1016/j.technovation.2005.09.008

Perdomo, J., González, J. y Galende, J. (2009). The intervening effect of business innovation capability on the relationship between Total Quality Management and technological innovation. International Journal of Production Research, 47 (18), September 15, 5087–5107. https://doi.org/10.1080/00207540802070934.

Porter, M. (2009). Estrategia Competitiva: Técnicas para el análisis de la empresa y sus competidores. España: Ediciones Pirámide.

Prajogo, D.I. y Sohal, A.S., (2001). TQM and innovation: a literature review and research framework, *Technovation* 21, 539–558. https://doi.org/10.1016/S0166-4972(00)00070-5

Prajogo, D. I. y Sohal, A. S. (2003). The relationship between TQM practices, quality performance, and innovation performance: An empirical examination, *The International Journal of Quality y Reliability Management,* 20 (8/9), 901-918. https://doi.org/10.1108/02656710310493625.

Prajogo, D. I. y Sohal, A. S. (2004a). The Sustainability and Evolution of Quality Improvement Programmes-an Australian Case Study, *Total Quality Management y Business Excellence*, 15 (2), 205-220. http://dx.doi.org/10.1080/1478336032000149036.

Prajogo, D. I. y Sohal, A. S. (2004b). Transitioning from total quality management to total innovative management: An Australian case, *The International Journal of Quality y Reliability Management*, 21 (8), 861-875. https://doi.org/10.1108/02656710410551746.

Prajogo, D. I. y Sohal, A. S. (2004c). The multidimensionality of TQM practices in determining quality and innovation performance - an empirical examination, *Technovation*, 24 (6), 443-453. https://doi.org/10.1016/S0166-4972(02)00122-0.

Prajogo, D. I. y Sohal, A. S. (2006a). The integration of TQM and technology/RyD management in determining quality and innovation performance, Omega, 34 (3), 296-312. https://doi.org/10.1016/j.omega.2004.11.004.

Prajogo, D. I. y Sohal, A.S., (2006b). The relationship between organization strategy, total quality management (TQM), and organization performance - the mediating role of TQM, *European Journal of Operational Research,* 168 (1) 35-50. https://doi.org/10.1016/j.ejor.2004.03.033.

Reed, R., Lemak, D. J., y Mongomery, J. C. (1996). Beyond process: TQM content and firm performance. *Academy of Management Review,* 21(1) 173–202. https://doi.org/10.5465/amr.1996.9602161569.

Rodríguez-Pose, A., y Villarreal, E. M. (2015). Innovation and regional growth in Mexico: 2000–2010. *Growth and Change,* 46(2) 172-195. http://dx.doi.org/10.1111/grow.12102.

Ruiz, M., Pardo, A, y San Martín, R. (2010). Modelos de Ecuaciones Estructurales. *Papeles del Psicólogo*, 31(1), 34-45. Disponible en: https://www.redalyc.org/pdf/778/77812441004.pdf Consultado: 19/02/2018

Salguero, J., Muñoz-Cauqui, M. C., Batista, M., Calvino, A., Aguayo, F., y Marcos, M. (2015). R&D&I management system in distributed manufacturing systems. *Procedia Engineering*, 132, 54-61. https://doi.org/10.1016/j.proeng.2015.12.479

Samson, D., y Terziovski, M. (1999). The relationship between total quality management practices and operational performance. *Journal of operations management*, 17(4) 393-409. http://dx.doi.org/10.1016/S0272-6963(98)00046-1.

Santos, M. L. y Álvarez, L. I. (2008). Efectos de la Gestión de Calidad Total en la Transformación en la Innovación Tecnológica y Administrativa. *Cuadernos de Economía y Dirección de la Empresa*, 37, diciembre, 33-65. https://doi.org/10.1016/S1138-5758(08)70068-9.

Satish, K. P. y Srinivasan, R. (2010). Total Quality Management and Innovation Performance: An Empirical Study on the Interrelationships and Effects. *South Asian Journal of Management*, 17 (3) 8-22. Disponible en: https://search.proquest.com/docview/807667436 Consultado: 19/02/2018.

Saunders, M., Lewis, P. y Thornhill, A. (2009). *Research methods for business students*, 5ª ed. London. Harlow: Financial Times-Prentice Hall.

Sila, I. y Ebrahimpour, M. (2003). Examination and comparison of the critical factors of total quality management (TQM) across countries. *International Journal of Production Research*, 41 (2) 235-268. http://dx.doi.org/10.1080/0020754021000022212.

Singh, P. J. y Smith, A. J. R. (2004). Relationship between TQM and innovation: an empirical study, *Journal of Manufacturing Technology Management,* 15 (5) 394-401. https://doi.org/10.1108/17410380410540381.

Tasleem, M., Khan, N., y Masood, S. A. (2016). Impact of TQM and Technology Management on Organizational Performance. *Mehran University Research Journal of Engineering and Technology*, 35 (4), 585-598. https://doi.org/10.22581/muet1982.1604.10

Taylor R., y Pearson A. W. (1994). Total quality management in research and development. *TQM Magazine*, 6 (1), 26–34. https://doi.org/10.1108/09544789410052723

Velasco E., Zamanillo I. y Gurutze, M. (2007). *Evolución de los modelos sobre el proceso de innovación: desde el modelo lineal hasta los sistemas de innovación*. XX Congreso anual de AEDEM. Palma de Mallorca. Disponible en: https://dialnet.unirioja.es/servlet/articulo?codigo=2499438 Consultado: 19/02/2018.

Westphal, J. D., Gulati, R. y Shortell, S. M. (1997). Customization or conformity? An institutional and network perspective on the content and consequences of TQM adoption. *Administrative Science Quartely,* 42 (2) 366-394. http://dx.doi.org/10.2307/2393924

Yusr, M. M., Mohd, S. S., y Othman, A. R. (2014). The effect of TQM practices on technological innovation capabilities: applying on Malaysian manufacturing sector. *International Journal for Quality Research*, 8(2) 197-216. Disponible en: http://www.ijqr.net/journal/v8-n2/5.pdf Consultado: 19/02/2018.

Zairi, M., (1999). Best Practice Process Innovation Management. Oxford, Butterworth Heinemann.