# Innovative Business Behavior and Its Context: The Case of a Turbo Parts Company

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**Abstract**
The purpose of this document is to analyze the accumulation of technological capabilities and their interrelation with the spheres of context in a Mexican turbo parts company called Omega. The methodological design was that of a case study conducted with semi-structured interviews. The results show the accumulation of technological capabilities as driven by the catalyst of business and management capabilities, with R&D playing a relevant role at different levels of innovation. Regarding the spheres of context, the link with universities, research centers, CONAHCYT (National Commission for Humanities, Science and Technology), clients and suppliers has been a valuable resource for Omega. In the economic sphere, the perception of an unserved market and the drive to get ahead of the competition stand out. In the environmental sphere, the influence of client-requested environmental regulations, and in the political sphere, the effect of international industrial safety standards, have been a determining factor in several innovation decisions of the company. Finally, in the social and cultural spheres, the business environment of Querétaro stands out and the links with research centers, access to the PEI (Program of Economic Incentives) and the accumulated technological capabilities of the founder and the R&D director were the key elements for the birth and positioning of Omega as one of the main technology-based companies in Mexico and the world specialized in its field.

**Keywords:** technological capabilities, case study, context spheres, Mexico, CoPS, innovation policy.

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## Introduction

There is agreement on the importance of learning processes underlying the TCA (Accumulation of Technological Capabilities) in developed economies (Lundvall, 2016). The successful case of the "Southeast Tigers" bore important evidence on the effort of these countries to learn from technology transfer and innovate, in other words recognizing the importance of building TC (Technological Capabilities) (Dutrénit & Vera-Cruz, 2005). However, studies in other regions, primarily Latin America, did not yield such encouraging results because these innovative processes tended to be much more selective and uneven. Many scholars began to consider the differences in the context in which different companies are located to be important and raised the possibility that some factors may have influenced the TCA more than others. Recognition of the importance of the macroeconomic context as a generator of incentives for innovation dates back to the early 1980s. In an interesting study that attempts to evaluate the performance of infant industries, Bell et al. (1984) warns that behind the observed changes in productivity there may be cyclical components related to variations in the intensity of factor use due to fluctuations in demand and the availability of intermediate inputs. Katz (1986) and Katz et al. (2014) also point to certain characteristics of the macroeconomic context affecting innovation in Latin American economies.

Freeman (1995) defines the context and its influence on innovation and growth in five systems or spheres: science and technology, economic, political, social, and cultural. Freeman and Louçã (2001) added the environmental context. The scientific-technological sphere has perhaps been the most studied internationally (Lundvall & Johnson, 2016) and in Mexico (Casalet, 2013; Casas et al., 2013; Cimoli, 2013; Dutrénit, 2000) followed by the economic sphere (Katz & Astorga, 2014). The environmental sphere has received attention more recently (Domínguez, 2006; Heredia et al., 2022). But as Dutrénit et al. (2024) point out, there is a gap in the literature regarding how these different contextual spheres affect firms' TCA processes and innovation-related decisions. This paper seeks to contribute to the literature on this topic.

The objective of this paper is to analyze the TCA process in the company and the influence of context, encapsulated by the six spheres: science and technology, economic, environmental, social cultural and political following Dutrénit et al. (2024).

The case of both the catching up and the innovations of a late comer like Omega clearly demonstrates the technological effort behind the different sources of learning proposed by Lundvall (2016). Throughout this paper, we will show how a company's TCA, in a process like that described by Bell and Figueiredo (2012), moves from technology imitation based on a very limited innovative capacity to deeper levels in progressive stages of technological innovation with its own design and brand manufacturing. An important fact to consider in the process of TCA is that turbine and turbo parts are not mass-produced consumer goods, but low volume, high-technology, high-value capital goods, which are referred as CoPS (Complex Products and Systems) (Chudnovsky et al.,1983 ). The point is that these firms follow different paths of TCA as this author and others (Kiamehr 2017 and Hobday 1998) maintain. The company began with the maintenance

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and operation of imported foreign systems, which provided them with the knowledge and capabilities needed to enter the capital goods manufacturing industry. Over time, they moved into modification and design activities, a path outlined by Chudnosky (1983) for CoPS. However important the internal learning process in Omega, there was also the external learning, where the influence of the context comes into play. This process occurred during a period of trade liberalization, with the signing of the free trade agreement that created windows of opportunity for Mexican entrepreneurs. Likewise, market demands tended to become more stringent, ensuring compliance with technological and environmental safety standards. Over time, a series of institutional, cultural, and social changes have occurred that have undoubtedly influenced business decisions.

This paper shows the complexity of Omega´s TC building process vis a vis the context encompassed by the six spheres which have had a great influence over the company´s technological decisions. Within the science and technology sphere, interaction with higher education and research institutions and the support of governmental incentives for innovation are clearly evident. Customer requirements have also been a factor driving innovative solutions. From the perspective of the economic sphere, demand and competition have been critical factors in Omega's decisions. Likewise, market demands tended to become more stringent, ensuring compliance with technological and environmental safety standards and environmental protection regulations in Mexico and around the world, contributing to defining the direction of R&D and investments. The political sphere, through the regulation of industrial safety and compliance with labor rights, has been a fundamental element of the institutional environment that has influenced business decisions. In the social sphere, Omega has managed to overcome the shortage of qualified personnel thanks to the process of decentralizing industrial activity from the center of the country and the growing presence of regional universities and technology centers. Finally, the influence of civil organizations and entities, as well as values, are present in the company's standards of conduct and technological strategy. Throughout Mexico's industrialization, the metalworking capital goods industry, particularly in domestically owned companies, has lagged considerably behind durable and non-durable consumer goods and commodity production. Omega's case can therefore be considered paradigmatic for its technological efforts to build its innovative capabilities.

The following section, Methodological Aspects, presents the different actions used to examine the company. The section, *Organizational Structure, Market, and Company Resources*, analyzes these aspects with respect to products, personnel employed, R&D expenditure, and patents. The section, *Learning and Building Technological Capabilities According to Technical Functio*ns, presents the degree of advancement of the company's TCA with reference to these technical functions. The section, *How Has the Context Influenced Decisions Concerning TCA?* analyzes, following the guidelines set forth in Dutrénit et al. (2024), the influence of the science and technology, the economic, environmental, political, social, and cultural spheres on investment decisions related to technical change. Finally, the section, *Reflections on Relevant Factors of TCA* in Omega, presents the conclusions.

## Methodology

This is an exploratory case study (Verdugo-Castro et al., 2022) with semi-structured, in-depth, face-to-face interviews. The interview guide was designed to answer the following questions:

a) What are the characteristics of TCA according to the different technical functions (decision-making for: technology adoption and development, development of process technologies and new products, linking with other actors, and integration of exponential technologies)?

b) To what extent does context involved in the mentioned spheres influence the company's behavior with respect to TCA processes?

c) Which indicators of the spheres have the greatest influence depending on the different economic activity sectors in which the company operates?

d) What mechanisms does the company adopt to adapt its TCA processes to changes in the spheres?

Three corporate directors were interviewed: the R&D director (Interviewee I), aeronautics director (Interviewee II) and the corporate manager and founder who has turbo parts and overall company management (Interviewee III). It was also possible to speak for a short while with the engineering manager and a young woman engineer employed in R&D. Three five-hour visits were conducted around the plants, where we were able to examine infrastructure, equipment and operations. The "TC Matrix with Digital Transformation Processes" developed by Dutrénit et al. (2024) was used to complete the interviews to assess the company's progress in each of its technical functions. The director of the R&D division indicated the percentage of progress in each of the items. Finally, since it was not possible to meet the corporate director (Interviewee III) in person, we asked virtually a set of five open-ended Likert-type questions to examine his perception of the influence of the economic sphere on investment and technological strategy decisions.

It may be rightly said that there is a bias in an analysis solely based on interviews. We were not able to consult any financial accounts of the company, which are confidential as, similar to most small firms in Mexico, this is a family business. Nevertheless, we did consult an internal company document in which there was detailed information about the technological strategy of the company, certifications, patents, alliances with other firms and contracts. This was a document handed in to us by the head of the R&D division. Also, through external sources we were able to examine official information on patents in the Mexican Institute of Intellectual Property (IMPI) and Conahcyt data bases, and it was verified that Omega is a regular supplier company for the different divisions of Pemex, the Mexican oil company in Pemex data bases[1].

[1] https://www.pemex.com/ri/finanzas/Resultados%20anuales/Anexos several issues

## Organizational structure, market and company resources

Omega is a company located in the field of CoPS, which, unlike consumer goods or inputs that are produced on a large scale for an expected demand, are produced in small quantities with a small demand subject to the orders of their clients with a high concentration in the supply market (Chudnovsky, 1998). In CoPS, as Kiamerh (2017) points out in his analysis of a latecomer dedicated to the production of hydroelectric electricity generation systems in Iran, the learning patterns differ from those analyzed in the literature for goods produced on a large scale. In the TCA process, deliberate actions to learn and innovate are evident: leveraging the company's resources, strategically recruiting experienced engineers, conducting R&D in-house, as well as protecting its innovations with patents and linking with research centers and universities and suppliers.

Founded in the 1990s by an entrepreneur with extensive national and international experience in the sector, the company began with the maintenance and operation of imported foreign systems, which provided the knowledge and capabilities for it to enter the capital goods manufacturing industry. Over time, they moved into modification and design activities (Chudnosky, 1983).

## Company resources

Omega's management organization is reflected in a divisional structure consisting of a general management team under which there are three divisions: turbo parts, aeronautics, and research and development (R&D). The three divisions are geographically co-located, each with a dedicated plant. Their business units correspond to the product lines that are their main sources of profitability. These divisions exhibit a high degree of complementarity in terms of infrastructure and support teams, both labor and technical, as can be seen in the following section.

In terms of production, the turbo parts division accounts for the largest percentage of sales (86%), while the other two divisions each account for 7% (Table 1). This division's main products are refurbishments of centrifugal compressors and their components, steam turbines and their components, and comprehensive field projects (gas and oil). These are sold in the domestic market. Its position in the supply chain is Tier 2.

The company diversified into the aeronautical market in 2010. The aeronautical division's products include landing gear parts, fuel system components, and peripherals for aeronautical engines and aircraft and fuselage interiors. Most of these are sold internationally or to companies in the global value chain (Tier 3).

Although internal R&D activities were previously carried out, the R&D division emerged as a subsidiary of Omega in 2016. The R&D division has been crucial to the company's TCA. It has designed and manufactured dry seals for compressors and steam turbines and has carried out analysis and manufacturing projects for the turbomachinery industry.

**Table 1.** Distribution of Omega production. specialized suppliers.

| División | % sales | Featured Products | Destination market |
|---|---|---|---|
| Turbo parts | 86 | Rehabilitation of centrifugal compressors and components.<br>Rehabilitation of steam turbines and components. Comprehensive field projects (oil and gas) | National |
| Aeronautics | 7 | Landing gear parts<br>Fuel system and peripheral components<br>Airplane engine components<br>Aircraft interiors and fuselage components.<br>Dry seals for compressors and steam turbines. Replacement spare parts and maintenance services for industrial turbines. | USA and Canada |
| R&D | 7 | Analysis of projects and special manufacturing for the turbine machinery industry and others | USA and Canada |
| Total | 100% | | |

Source: Information granted by the firm.

## Strategic recruitment of engineers with extensive experience

The strategy has been to recruit managers with prior experience in their respective fields and engineering talent to head the three divisions. Currently, there are 185 employees, of whom 110 (59%) are vocational training personnel, especially engineers; the remainder are operational personnel (Table 2). The R&D division has the highest percentage of professionals and technicians, comprising 90% of its total workforce, followed by the turbo parts division with 54% and the aeronautics division with 51%. Also of interest is the number of women: in the R&D division, it reaches 27%, followed by the aeronautics division with 20%, and with a woman as division director.

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**Table 2**. Personnel distribution at Omega. Information provided by corporate staff.

| Division | Number of employees | Number of professionals and technicians | Number of operational and support staff | Number of women | average age (years) |
|---|---|---|---|---|---|
| Turbo parts | 120 | 65 | 55 | 15 | 39 |
| Aeronautics | 35 | 18 | 17 | 5 | 30 |
| R&D | 30 | 27 | 3 | 8 | 32 |
| Total: | 185 | 110 | 75 | 28 | |

Source: Information granted by the firm.

In all three divisions, there are Mexican engineers at different levels, from interns, recent graduates, and thesis students to doctoral level. In the opinion of the chief of engineering the technical preparation of engineers coming from the different universities and technological institutes is sound, although some may lack soft skills.

If we start from the notion that a company is the sum of its resources, and that these are crucial to understanding the nature of its evolution and growth (Penrose, 2009) as presented in this section, inherited resources (the prior experience of the entrepreneur and managers) influenced the direction of Omega's future expansion. That is, the combination of entrepreneurial spirit, managerial ability, and a technical team has been a primary factor in recognizing productive opportunities through TCA.

## Protecting their innovations

The company has achieved eight different certifications for its various processes and products, establishing it as a reliable international supplier. Table 3 lists the technological appropriability of its new products. Most of these patents and trademarks have been registered in Mexico. A trademark was registered in the United States. The company invests 15% of its EBITDA[2] margin, equivalent to between 3% and 5% of its sales.

**Table 3**. OMEGA's intellectual property registration activity

| Year of registry | Registry granting | Name |
|---|---|---|
| 2016 | 2018 | Vibration control – Mexico |
| 2017 | Not concluded | Three-layer sealing face for dry seal- Mexico |
| 2018 | 2021 | Gas- bearing steam turbine - Mexico |
| 2018 | 2021 | Seal with lubrical coating- Mexico |
| 2018 | 2020 | Steam turbines trade-mark OMEGA-1100® y OMEGA-1100-LA® - Mexico |
| 2018 | 2018 | Trade-mark OMEGA GREEN, Clean generation, Mexico |
| 2020 | In process | High-performance dry seal- Mexico (in progress) |
| 2021 | 2022 | Dry seal panel pipe washing equipment- Mexico (in progress) |
| 2021 | 2023 | Trade-mark OMEGA- United States Of America |

Source: Information granted by the firm verified in the IMPI data base.

## Learning and Building Technological Capabilities According to Technical Functions

In Omega's TCA process, what Lundvall (2016, pp.21) states is true: "innovations are the result of collisions between technological opportunity and user needs." Throughout the company's evolution, a learning process stands out, in which learning from experience or learning by producing, learning by interacting, and learning through R&D are distinguished, which can be seen in the ACT analysis regarding the "CT matrix with digital transformation processes" (Dutrénit et al., 2024).

Table 4 shows the capabilities matrix according to the information provided by Interviewee I. The columns of the matrix are dedicated to the capabilities developed in each function. The rows present the degree of advancement of these capabilities (routine, basic, intermediate, and advanced innovative TC). The latter refers to leadership, use of disruptive technologies in the design of new products, and integration into all processes. The degree of advancement of each function is categorized in grayscale. Dark gray indicates less than 50% advancement, light gray indicates 50% to 69%, and white indicates 70% to 100%.

[2] Earnings before interest, taxes, depreciation and amortization. A company´s profits in a particular period, before taking away amounts for interest paid.

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**Table 4.** Technological capabilities matrix for Omega

| **Technological capabilities level** | **Decision making for the adoption and development of technologies** | **Adopt, adapt, and develop process technologies** | **New product development** | **Linkages with other actors** | **Integration of exponential technologies** |
|---|---|---|---|---|---|
| **Rutinary** | Raising awareness about the need to adopt technologies (**100%**) | Routine operation and basic maintenance of facilities (**100%**) | Replica of fix specifications and designs (**100%**) | Search of available inputs and providers of existing technologies. (**100%**) | DT Identification TD for general purposes of the firm (**10%**) |
| | | Improving efficiency through existing tasks (**50%**) | Rutinary quality control to maintain existing standards and specifications (**100%**) | Customer information and absorption search and (**100%**) | Raising awareness about the use and implementation of DT (**10%**) |
| **Innovative TC (Basic)** | Defined responsibilities for decision making (**100%**) | Extending the useful life of equipment (modernization, adaptation of attachments) (**70%**) | **Minor adaptations based on market needs and incremental improvement in product performance characteristics 100%)** | Search and absorption of information and DT from new providers, customers, and local and international institutions (**100%**) | Design of DT adoption and implementation strategies (**10%**) |
| | | Minor adaptations of equipment and processes to increase efficiency (**70%**) | | Search for new market niches (**80%**) | |
| | | Introduction of sensors to acquire information for quality assurance (40%) | | | |
| Innovative TC (Intermediate) | Define an adoption strategy according to current customer requirements (100%) | Automation of equipment and processes (**70%**) | Substantial improvements in product design from development activities (**100%**) | Technological vigilance (**70%**) | Implementation of DT (robotics, AI, data analytics, cybersecurity) for the design of new products, processes and marketing (**0%**) |
| | Regular meetings and tools for decision making (**70%**) | Incremental design for new processes. (**50%**) | Generation of technological assets (IPR and industrial secrets) (**90%**) | Incremental development of product and processes with customers and suppliers (**90%**) | |
| | Adoption-use of some DT (Digital Technologies) for decision making (data analytics, etc.) (**0%**) | Use of DT in some productive processes and in logistics (0%) | Digitalization of developments (**90%**) | Linkages with local universities (**100%**) | |
| | | Occasional non systematical incorporation of robots (**60%**) | Use of some DT (AI or data analytics) (**0%**) | Interaction with other actors: academia, government, competitors, or other local industries to share information and influence public policies (**50%**) | |
| | | | | Acceso a apoyos públicos de apoyo a la innovación (Antes del 2018: **100%,** Después del 2018: **10%**) | |
| Innovative TC (Advanced) | Design and experimental strategy to anticipate market needs and develop technological leadership (**80%**) | **Process innovation and related R&D development (60%)** | Product innovation and R&D development (**80%**) | Linkage to monitor technological trends, markets, and international regulation (**0%**) | Integration of DT in all processes (manufacturing, logistics, marketing-smart factory) and new products design (**0%**) |
| | | Systematical use of TD in productive processes and logistics (AI) (**0%**) | Systematical use of DT for product design (**10%**) | Linkages with international universities and research centers (**100%**) | |
| | | Systematical use of robots and digitalization of the information generated. (**10%**) | | Collaboration in technological developments with suppliers, customers, competitors with an open innovation approach (**20%**) | |

Source: Information provided by Omega CEO.

| Nomenclature |
|---|
| 0-49% |
| 50-69% |
| 70-100% |

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### Decision-making capabilities for technology adoption and development

In this role, progress is at the top level in all areas except one. The founder's work experience gave him market knowledge and an innovative vision, and he was also aware of the need to adopt technologies and have an organizational structure for efficient technological decision-making. At the intermediate capability level, his technology adoption strategy is being integrated through an analysis of the needs of oil industry users. At the same time, there is a knowledge transfer process that applies, shares, and provides feedback to all divisions, leveraging the ideas, innovations, and proposals that emerge within a cross-discipline service model.

The quest to understand scientific and technological principles through R&D constitutes, as Lundvall (2016) points out, a third form of learning, which is Omega's strategy for investing in R&D in 2009. The company has managed to establish regular meetings and decision-making tools (Interviewee I). The exception is that they have not adopted the use of TD (digital technologies) for decision-making (e.g., data analytics, etc.).

**Capabilities to adopt, adapt and develop process technologies.**
Of the aspects highlighted in this function, Omega has advanced between 70% and 100% in i) the routine operation and basic maintenance of facilities, in ii) the extension of the useful life of the equipment (modernization and adaptation of attachments), in iii) minor adaptations of equipment and processes to increase efficiency and design the necessary equipment for the production of seals such as the test bench (equipment that Omega designed with its own technology) and the console to manufacture the seals that has an algorithm that they developed to measure their mechanical properties. The same progress has been made in relation to iv) the automation of some equipment and processes. On the other hand, the company considers it has achieved intermediate progress (between 50% and 69%) in i) efficiency improvements based on experience in existing tasks, ii) incremental design of new processes, iii) eventual incorporation of robots, and iv) process innovation and related R&D development. Finally, progress is lower in the following areas: i) introduction of sensors to acquire quality assurance information, ii) use of digital transformation in production and logistics processes, and iii) systematic use of digitalization of the information generated.

**Capabilities to develop new products.**
In this function, almost all items show progress between 70% and 100%. The critical factor in turbomachinery is fluid leakage, which represents an economic loss, for example, oil. Therefore, coatings and seals are important for eliminating it. This has been the basis for the company's creation of new products.

In terms of replicating fixed specifications and designs, minor adaptations, and routine quality control, progress is 100%. As the market demanded more service, they evolved toward incremental improvements and, ultimately, substantive improvements in product design based on their R&D activities (Table 4). These are not necessarily world-class products, but rather ones that did not exist on the market, so they required a reverse engineering process combined with the development of their own technology.

The most important result of the first stage was the console, which allowed them to model and build the first dry seals; in other words, they developed a product that is a capital asset. The console's manufacturing and operation were such a success that Omega decided not to register the patent to avoid disseminating trade secrets. The next product was the test bench, which is a device that simulates the operating conditions to which the dry seal will be subjected.

As Interviewee I points out, there is a great deal of uncertainty in the innovation process:

"It took us two years to build it [the stamp console], and the fruits of this effort began to be marketed 10 years later. Research is like that; it doesn't show up immediately; it takes years to pay off, but the machine is physically there, working."

This equipment is difficult to find on the market because it must be adapted to the specific specifications of the seals. Omega is the only dry seal manufacturer in Mexico and one of the five producers of turbine seals for the oil industry. Although smaller than other competitors, it has the competitive advantage of being a niche manufacturer with customized solutions.

Omega subsequently developed seals with new geometries that would allow them to adapt to more complex equipment without losing efficiency and performance, in addition to developing coatings. These were developed with the help of CIATEQ[3] researchers, using technology that replaces the usual and more expensive diamond coating. Other examples of TCA's advanced innovations are the following products: i) the compressor pipe washing machine, ii) the lapping machine, iii) gas turbine retrofitting, iv) gas turbine adaptation to solar energy, and v) manufacturing of environmentally friendly turbines.

> *"We are aware that the oil industry is in decline. In Europe, they are pioneers in clean energy. The division believes that [green turbines] might not be well received in Mexico due to our 20-30 years of technological backwardness, but we are thinking about exporting them to countries with advanced environmental issues and willing to pay for this technology."* (Interviewee 1)

Regarding the areas related to the generation of technological assets and industrial secrets, the R&D director considered this progress significant (Table 3), as did the digitalization of developments. On the other hand, regarding product innovation and related R&D development, as well as the systematic use of TDD for product design (Table 4), progress is less than 40%.

[3]Advanced Technology Center located in Querétaro México.

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**Capabilities to link with other actors.**

Concerning the linking function, Table 4 indicates that Omega has made considerable progress (70% or more). At the company's inception, the capabilities were routine: searching for available inputs, local and international suppliers, and existing technologies. Furthermore, the company conducts technological monitoring (70%), which has allowed it to discover new markets, and it stays informed about international regulatory changes.

Regarding the incremental development of products and processes with clients and suppliers, the company has made varying degrees of progress with customers from the oil, petrochemical and energy industries. However, in terms of collaboration on technological developments with suppliers, clients, competitors, and partners with an open innovation approach, this progress is incipient. Omega currently has collaborative relationships with universities and research centers, both public and private, with a 100% progress.

One area where they consider their progress to be moderate is interaction with other stakeholders to share information and influence public policy. Finally, in terms of networking to monitor technological trends, as well as collaboration on technological developments with clients and suppliers with an open innovation approach, progress is at its lowest level.

**Capabilities to integrate exponential technologies.**

This is an area in which progress is slow. Omega reported a 10% progress at both routine and basic levels. It has not made progress toward implementing TD (robotics, AI, data analytics, etc.) for the design and development of new products, processes, and marketing. However, it has implemented digital transformation on the console and test bench for parameter mapping and recording, and for simulation. Engineers also design and simulate prototypes and present their proposals in digital models. In our opinion, it is important to keep in mind that Omega, as a CoPS firm is a technology-based company dedicated to developing customized solutions for its clients, so it is understandable that this is not a priority in its technological strategy. Its R&D activities have focused primarily on improving and innovating its products. This has been accompanied by the incorporation of digital technologies and parameter mapping algorithms in some production lines or equipment as required.

## How has the context influenced decisions concerning the TCA?

**Science and technology sphere**

Following Dutrénit et al. (2024), this sphere encompasses organizations, public entities, and subsystems of society, as well as individuals engaged in the advancement of knowledge about the natural or social world, the evolution of artifacts and techniques, their design, development, and improvement, and the recording and dissemination of knowledge used for these activities. For several decades, government actions favoring research centers, universities, and companies were implemented, especially between 2009 and 2018 with the creation of the PEI (Conahcyt, 2009). However, these types of incentives have been in place since 2001 (Fujii and Huffman, 2008). The following shows the influence on Omega's innovative activities of i) universities and research centers, ii) leveraging innovation incentives, iii) collaboration with meso-institutions, and iv) links with other companies.

**Universities and Research Centers**

Contrary to the evidence found by Casas, de Gortari, and Luna (2013) regarding the weakness of collaboration between industry, universities, and research centers in Mexico, Omega's experience is very different. Omega currently collaborates with various national and international institutions. Among the national institutions are the most important public universities and research centers at the national and state level. Among the other private international research centers are the Southwest Research Institute (SWRI), Proenergy Services, and Ethos Energy. It is important to note that Omega is part of the Texas A&M International Turbomachinery Research Consortium, which reinforces its capacity for innovation.

As described above, the relationship with CIATEQ has been very important in accumulating its technological capacity to develop new products. This connection illustrates learning through interaction (Lundvall, 2016).

**Leveraging incentives for innovation**

Between 2009 and 2018, Omega developed its most important projects thanks to the PEI, totaling access to 45 million Mexican pesos (2.25 million USD), 80% of which were carried with the state public innovation center. Omega estimates that by 2018, they had fully achieved access to public funds to support innovation; after this date, funding was suspended, and some projects were "left on the back burner." Although it was not mentioned during interviews, there is evidence of significant amounts of debt owed to suppliers by Pemex[4], which can have an impact on the company's finances or at least generate uncertainty in the company's technological decisions.

**Collaboration with meso-institutions**

Omega's aeronautics division belongs to FEMIA (Mexican Federation of the Aerospace Industry) and the Querétaro Air cluster, and its director serves on the boards of both institutions. This allows it to enjoy direct links with the Querétaro state government on matters of economic development. Now, regarding nearshoring, they point out that they have had much greater visibility of projects aligned with the capabilities not only of the company, but also of the cluster and the industry. They have established inter-cluster collaborations at the state level. This is to generate added value in projects, developments, new products, training, and the sharing of best practices, thus generating a multi-sector industrial ecosystem.

**Links with other companies**

As already noted, customer requirements often constitute a source of learning. An example of this was the need of an aeronautical client to reduce the production time of a part that was previously processed by

[4]https://www.pemex.com/ri/finanzas/Resultados%20anuales/Anexos%204T24_D.pdf

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another supplier. Omega requested a visit to the supplier to inspect the production process at the plant, where it analyzed and designed a process that radically changed the way the part was produced, moving from a 90% artisanal process to a 90% automated process, thanks to the innovation of the lapping machine. With this, Omega absorbed this process, and the client stopped using the other supplier's services. The words of Omega's R&D director allow us to appreciate the importance of Omega's customer-supplier relationship:

"One of the most complex challenges in developing this project was understanding the specifications, for which we received a lot of support, and then implementing those specifications. The rest is work... that's what engineering is all about. I think good engineering can do it, but the important thing in our case was the opportunity. The fact that we're so close to each other is a very strong competitive advantage that gives us the opportunity to do it."

Finally, the alliances established by the company illustrate the importance of interactive learning, which has allowed it to advance along its technological path.

**Economic Sphere**
The economic sphere encompasses "the subsystems of society primarily concerned with the production, distribution, and consumption of goods and services, and the individuals and organizations engaged in these activities" (Dutrénit et al., 2024). Its influence is expressed through changes in price indicators (interest rates, real exchange rates, tariffs, etc.) or industrial program incentives, market size and growth, future market expectations, and the structure of competition. To assess the importance of the economic sphere for the company's director and founder, the following decision topics were raised for analysis: 1) Starting of the company in 1991, 2) Selection of the state of Querétaro as the company's location, 3) Diversification into the aeronautical industry in 2009, 4) Factors influencing investment in the R&D division, and , finally, a hypothesis-based question was posed to examine 5) what factors are taken into account if two divisions presented alternative technological projects and, due to scarce resources, only one of them must be chosen. The multiple options of which were rated from 1 to 6 points. The answers give light on the relative importance of the different factors.

**The starting of the company in 1991**
Two factors were decisive, which received the highest scores: a) the owner's prior experience in the industry (6 points) and c) the perception of an opportunity in a market not served by competitors (5 points); d) the favorable exchange rate received 3 points, i.e., a medium influence; e) the stable macro economy received 2 points. Interesting to note that a) market openness and the next NAFTA signing, after the company's formation, received one point, which is understandable because the company's market would be domestic.
Company location in the state of Querétaro

The most important factor came under f) "other" with 6 points: The explanation was that the owner lived in Querétaro and had arrived in the state years before to work for a previously established company in the sector that closed, leaving behind experience to start the new company; b) Good infrastructure and services for the industry and c) Querétaro's good location for industrial activity got 3 points.
Diversification into aeronautics.

The establishment of an Air Cluster in Querétaro was received the highest importance (6 points); the existence of incentives (3), c) the existence of synergies, technological experience, and the creation of the Querétaro Aeronautical University each received 2 points. It is important to highlight that financing opportunities received only one point.

**Factors influencing investment in the R&D division.**
The two most important factors were the need c) "the need to be ahead of the competition" with 5 points, and a) "customer suggestions" with 4 points. Next in line were supply-side factors with 3 points: d) "knowledge of technological trajectories" and e) "capabilities leveraged" and f) the pursuit of economies of scale had one point. Interestingly, the presence of economic incentives had two points.
What factors are considered if two divisions presented alternative technological projects?

In this case, a) "staying ahead of the competition" obtained 6 points and b) "the existence of a potential market" with 5 points. c) Expected profits was ranked very low with 2 points and the interest rate with one point. In conclusion, regarding the influence of the economic sphere on decisions leading to technical change in the company, the perception of an unserved market, that is, the presence of demand, the notion of staying ahead of the competition, and the goal of achieving greater market share are the most relevant factors. Stable Macro economy and exchange rates were in the middle (or even low, like the interest rate). The regional context also remains of medium influence. It is important to highlight the mention of the positive effect of the government's orientation towards the oil sector (See Table 5 for a summary of the most relevant variables in the context).

**Environmental Sphere**
This sphere concerns the actions derived from individuals, organizations, and public administrations regarding environmental protection and sustainable development (Dutrénit et al., 2024). The beginning of an environmental policy dates back to the mid-1980s in Mexico. In the 1990s, the signing of NAFTA (North America Free Trade Agreement) accelerated the development of the environmental regulatory framework and the institutional change required for the implementation of this policy. This framework evolved in terms of regulations, incorporation of voluntary instruments, and it can be said that some communities, in the case of neighboring companies, began to exert pressure for compliance with the regulations. Additional pressure came from international clients of exporting companies, which prompted companies to improve their environmental performance (Domínguez, 2006). The processes do not represent an impact in terms of hazardous waste. Much of the waste, resulting from specialized machining processes, can be reused by other companies. Therefore, the separation and cleaning of waste within the plants allows them to maintain the plant in cleaner conditions and market it to companies interested in using it (Table 5).

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On the other hand, the pressure on the aerospace industry to reduce its carbon footprint is passed on to its customers. In the case of the aeronautics division, one response has been to rethink its packaging to make it reusable. They have also sought to optimize lead times to reduce energy use.

Omega is currently developing the following projects: Solar gas turbines. ii) Longer-life steam turbines, iii) Steam turbines with pneumatic bearings that replace petroleum-based lubricant with air.

In some cases, they have arisen from understanding their clients' current needs, while in others, they are a perception of future demand due to global environmental regulatory trends. In the last respect, following the R&D director's review of API (American Petroleum Institute) regulatory changes, Omega decided to design and manufacture a machine for washing compressor tubing, as the new standard requires this function for equipment audits. In other words, by staying up-to-date on industrial standards, the company is ahead of what its clients will demand in the near future.

**Social Sphere**

This sphere refers to the relationships between people, organizations, and civil entities that structure society and on which the degrees of inequality, inequity, and asymmetry within it depend in relation to the availability of resources and income (Dutrénit et al., 2024).

A key issue for companies is the availability of personnel with the required level of qualifications. Since the process of decentralization of industrial activity from the center of the country, Querétaro is receiving a workforce from central Mexico. This workforce is not only composed of unskilled labor, but interviewees also indicated that the number of specialized talent available to fill executive positions and develop knowledge is increasing (Table 5).

**Cultural Sphere**

This sphere encompasses the ideas, values, artistic creations, traditions, religions, and customs that influence the standards of conduct of the individuals and organizations that promote them and impact the rules of society (Dutrénit et al., 2024). OMEGA's innovative culture stems in part from the founders' and managers' culture of working and studying in foreign countries or companies. However, it is also important to consider the business environment in Querétaro, where there are a number of exporting automotive companies, leading plastics manufacturers, and companies from large Mexican industrial groups. As noted in the second section, the company's founding was driven by the idea of creating technology, especially Mexican technology, although it is accepted that complete technological independence is not possible. According to our interviewees I and II, the innovative culture unites students and engineers, resulting in low staff turnover which was confirmed by the young engineer who expressed the enthusiasm that reigns in the team.

**Table 5.** Context variables with the greatest impact on Omega's ACT

| SPHERE | Variable | IMPACT | RESULT | IMPORTANCE |
|---|---|---|---|---|
| ECONOMIC | PERCEPTION OF A NON SERVED MARKET | + | COMPANY CREATION | HIGH |
| | STAYING AHEAD OF COMPETITION | | DECISION TO INVEST A LARGE SUM IN R&D | HIGH |
| | | | DECISION TO ENTER THE DRY SEALS AND ECOFRIENDLY TURBINES BUSINESS | HIGH |
| | PREEXISTENCE OF DEMAND: PRESENCE OF THE AIR CLUSTER | + | DIVERSIFICATION TO THE AERONAUTICS BUSINESS | |
| | FAVORABLE RATE OF EXCHANGE | + | COMPANY CREATION | MEDIUM |
| | | | DIVERSIFICATION TO THE AERONAUTICS BUSINESS | HIGH |
| | REGIONAL CONTEXT | | COMPANY CREATION | MEDIUM |
| SCIENCE AND TECHNOLOGY | ACCESS TO PUBLIC INNOVATION SUPPORT PROGRAMS | + | R&D DIVISION SPINOFF | HIGH |
| | | | LINKAGE WITH CIATEQ | HGH |
| | RESEARCH CENTERS CONSULTANCY | + | EQUIPMENT DESIGN AND MANUFACTURING (CONSOLE END TEST BENCH) | HIGH |
| | LINKS WITH UNIVERSITIES | + | STRATEGIC RECRUITMENT OF SPECIALIZED PERSONNEL | HGH |
| | | | INTERNATIONAL TURBOMACHINING RESEARCH CONSORTIUM WITH TEXAS A&M | HIGH |
| | LINKS WITH MESO LEVEL INSTITUTIONS | + | MEMBERANCE IN FEMIA AND THE QUERÉTARO AEROCLUSTER | MEDIUM |
| | | | INTERCLUSTER COLLABORATIONS | MEDIUM |
| | LINKS WITH CUTOMERS AND SUPPLIERS AND OTHER FIRMS. | + | COLLABORATION WITH THE CLIENT TO MANUFACTURE THE LAPPING MACHINE | HIGH |
| ENVIROMENTAL | ENVIROMENTAL LEGISLATION | + | REDUCTION OF SOLID WASTE | HIGH |
| | CUSTOMER REQUIREMENTS. | + | REDUCTION OF THE ECOLOGICAL FOOTPRINT IN PROCESSES AND PACKAGING IN THE AERONAUTICAL DIVISION<br>CREATION OF ECO-FRIENDLY TURBINES IN THE TURBOMACHINERY DIVISION | HIGH |
| | INTERNATIONAL REGULATORY CHANGES TOWARDS GREATER INDUSTRIAL SECURITY | + | DESIGN AND MANUFACTURE OF THE PIPE WASHING MACHINE | ALTA |
| SOCIAL | QUALIFIED PERSONELLE FROM UNIVERSITIES IN THE AREA | + | | ALTA |
| CULTURAL | ENTREPRENURIAL CULTURE | + | FOUNDER AND STAFF COMMITTED TO HIGH-PERFORMANCE ACHIEVEMENTS | ALTA |
| | REGIONAL BUSINESS CULTURE | + | OPPORTUNITY TO CONTACT DIFFERENT CLUSTERS | MEDIUM |

*Until 2018, when they were suspended
Source: Prepared by the authors based on interviews.

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## Final reflections

Throughout this paper, we have analyzed the company's TCA process and the influence of external factors that constitute the six mentioned spheres.

Observing the company's history allowed us to appreciate its various milestones: the ups and downs of starting a CoPS business, with the maintenance and operation of imported foreign systems through replication and reverse engineering, which gave them the knowledge and capabilities needed to enter into the manufacturing of capital goods, eventually graduating to modification and design activities. As Omega enhanced its engineering capabilities, more sophisticated optimization and design improvement activities were carried out in projects diversifying into the aeronautical industry, creating an R&D division, and designing and building its own capital equipment, which has allowed it to become a leading seal manufacturer on the continent, offering customized solutions. Furthermore, we observe that the company has the necessary resources to recognize and exploit productive opportunities through TCA: an entrepreneurial spirit with a vision to create its own technology and prior experience and market knowledge combined with the capacity of division managers who also had prior experience in their markets, and a growing team of engineers and technicians with high retention.

It is apparent that the company made consistent progress in building its technological base. In terms of decision-making for the adoption and development of technologies, the necessary steps were taken to design a technological strategy and the formation of an organizational structure that facilitated decision-making regarding necessary investments. Regarding the adoption and development of process technologies, it was possible to advance from the routine to the intermediate level with improvements in efficiency, introduction of computerized machinery, and construction of capital goods, which allowed for the development of the company's flagship products. In the new product development function, the company transitioned from replicating product specifications to new product design activities such as the test bench, the lapping machine, and dry seals. The prior experience of the founder and of the director of the R&D division provided insight into technology supply and the proposal of technological solutions. Omega also established relationships with public and private universities and research centers in Mexico and abroad, which has allowed it to strengthen its innovation capabilities. Finally, its progress in the integration of exponential technologies is relatively incipient. However, it should be noted that the company's activity does not require a high level of digitalization.

The next major question in this research concerns the influence of context on the TCA. Since its inception, the executive has been very close to CIATEQ, an institution with which they have carried out several projects with innovative results. Furthermore, Omega used the various instruments available through CONAHCYT to undertake these projects, particularly the PEI until the end of 2018, when they were eliminated, negatively impacting the company. Finally, the links with other companies in the form of technological alliances and the relationship with clients have been sources of learning. The latter, in particular, requested solutions to certain problems and, at the same time, promoted plant visits or provided information, as occurred in the design and construction of the lapping machine. This confirms the qualitative role of demand in promoting the TCA, as Lundvall (2016) points out.

For its part, the influence of the economic sphere on decisions leading to technical change in the company is expressed in two salient themes for the company's director: the perception of an unserved market and the notion of staying ahead of the competition. In this sense, belonging to the oil value chain ensured significant demand in the field of turbine maintenance, repair, and even refurbishment, which has constituted a lasting business opportunity. Something similar occurs with the presence of the Querétaro Air cluster, which integrates Omega into the global value chain of this industry. This confirms the role of demand pointed out by Bell and Pavitt (1995) and Katz and Astorga (2014), among others. Surprisingly, issues such as the presence of a stable macro economy, the signing of international treaties, and a favorable exchange rate were considered as being of only medium importance, surpassing only the interest rate as a factor of influence. Finally, the directors noted that the emphasis on the oil industry under this regime has favored the turbo parts market.

Regarding the environmental aspect, technological decisions are influenced both by the influence of its customers and by environmental regulations that have generated a change in processes and a demand for new environmentally friendly products such as solar turbines and steam turbine bearings.

Regarding the social aspect, the company has been able to overcome the shortage of qualified personnel with relative success, thanks to the increased supply of specialists from regional technological institutes and universities in Querétaro and surrounding states.

Finally, Mexican companies do not usually display a culture of innovation, much less one of the creations of their own technology, as is the case with Omega. Its innovative culture is influenced by the study and work of company executives in foreign countries or companies, its own values, as well as the business environment in Querétaro[5].

Limitations of this case study include the inability to interview more people dedicated to developing innovation, which may imply a subjective bias in the analysis. The corporate manager was generous in granting us time for the firm site inspection and interviewing those that take technological decisions in the company, but it is important to bear in mind that one of the characteristics of the company is being a family SME business with confidential financial accounts. Nonetheless we consulted the web site and other internal documents of the company and through external sources we were able to verify patent, trademarks, certifications, innovation incentives granted among other things. Thus, this study sheds some light on understanding the factors that influence decisions that promote innovation and offers some lessons for both businesses and economic policymakers.

[5]In regard to the political sphere, the interviewees did not consider this sphere relevant to their innovation decisions.

Technological independence cannot be neither complete, nor even desirable, but the case of OMEGA shows that there is significant room for innovation for Mexican companies if they take the necessary steps to explore opportunities with their own technology and not just import it. One issue for future research would be to compare these findings with other cases of companies with these characteristics (SMEs, family-owned, technology-based): are they facing similar obstacles to create their own technology? Also, it was possible see that OMEGA´s technological path was mostly one following customers' needs. However, the question remains for future research as to whether firms should endeavor in strategic technological planning to anticipate market needs.

Furthermore, since the elimination of CONAHCYT grants and incentives has affected Mexican firms, it is essential to resume public policy which favors technological innovation and supports science and to jointly establish the foundations for this to be a long-term policy that contributes to creating a pro-innovation culture nationwide; otherwise, Mexico's middle-income trap will never be overcome.

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