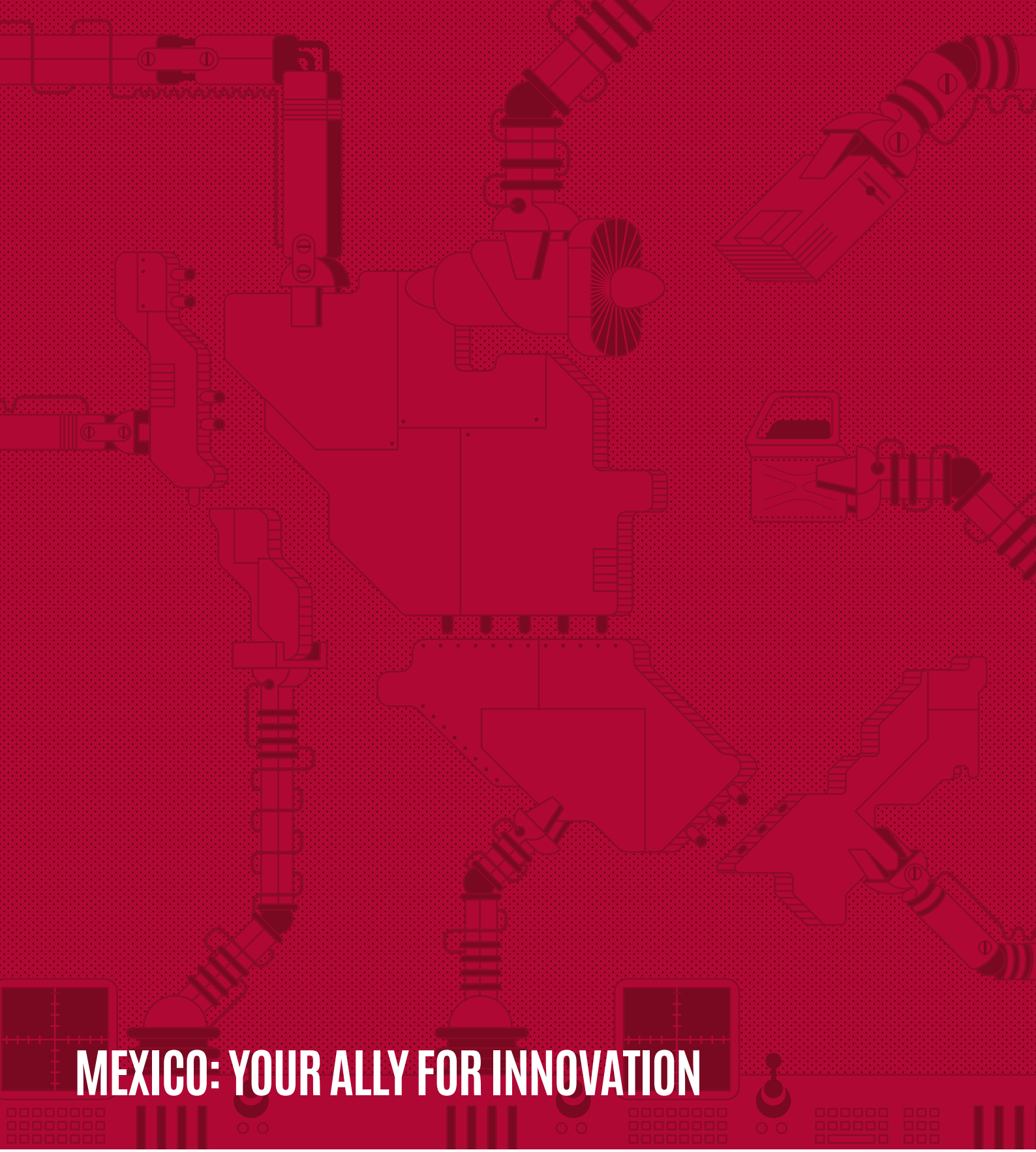

MEXICO: YOUR ALLY FOR INNOVATION

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MINISTRY OF ECONOMY

ESTADOS UNIDOS MEXICANOS

PRO MÉXICO
Trade and Investment

MEXICO:
YOUR ALLY FOR INNOVATION

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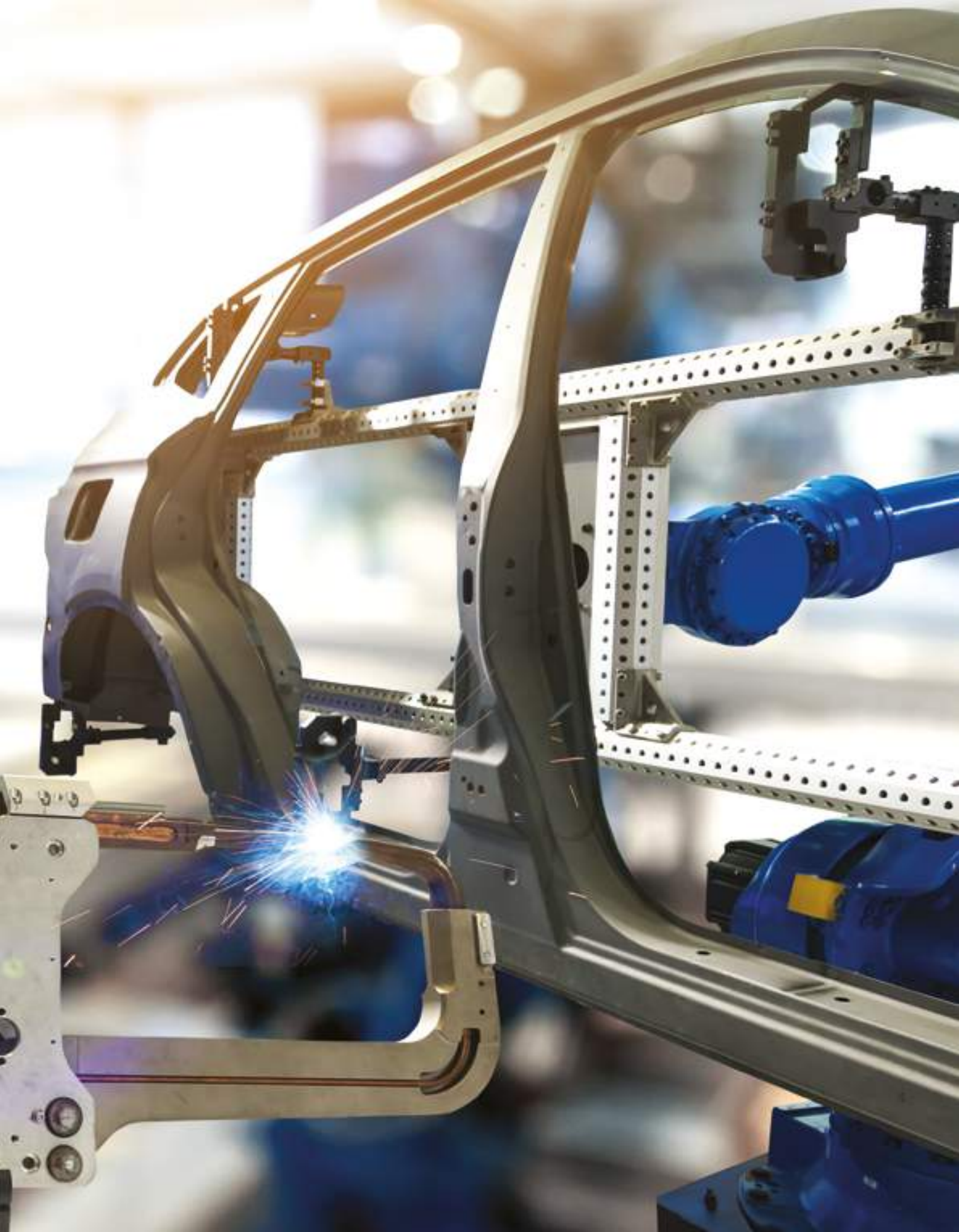


INTRODUCTION

We are aware of the importance of technology in our lives. More and more, technological developments applied to our wellbeing are becoming part of our daily lives, bringing with them new challenges as well as new possibilities. Thanks to these technological developments we have been able to integrate solutions that foster development, efficiency, productivity and comfort in areas ranging from production lines to traveling experiences.

At the industrial level, these innovative trends are creating a new productive ecosystem, integrating value chains, exporting services, and creating new solutions as these new cyber-physical systems converge. This is the key to understanding the Fourth Industrial Revolution, also known as Industry 4.0 (i4.0) —a term coined in Germany back in 2011.

These innovations have helped companies to reduce costs, increase production and productivity, conduct real-time monitoring, customize goods and services, and be environmentally friendly. Within this revolution, it is possible to identify at least five big trends that are leading the way in industry and that affect the technology, products, and processes used. These trends are digitalization, the Internet of Things (IoT), intelligent automation, energy decentralization, and 3D printing, all of which are relevant within the i4.0 framework.

Thus, it is necessary to examine and learn from what the leading companies are doing to update their operations, what governments in industrialized countries are doing to facilitate the adoption of these technologies, and what research institutions are doing in their fields, in order to move forward with their implementation in the productive sectors.

Thanks to the importance of its industrial production —mainly in manufacturing— and its positioning in global value chains, Mexico meets all the necessary conditions to ride this new wave of industrial innovation. However, a reactive vision will not suffice, and the country must prepare to make the most of this Fourth Industrial Revolution by determining its overall, current capacities, as well as its main industrial sectors' potential needs, to increase its international collaborations.

This is the scope of the book, which portrays Mexico as an established partner of the world leaders in industrial innovation. It depicts Mexico's present and future with regards to industrial innovation on Mexican industries and the main industrial technologies and enablers with which Mexico aims to become a significant player in global businesses. It also describes the importance of the manufacturing industry for the country's economy and includes details about six strategic sectors: aerospace, automotive, medical devices, electronics, and information technology.

The main goal is to become a reference book for those interested in learning about the industrial competitiveness outlook in Mexico, a country that is consolidating as a global manufacturing and exporting power.

The first part, entitled 'Industrial Competitiveness Outlook' describes the current state of the manufacturing industry and its sectors; while the second part, 'A Platform for Innovation', deals with Mexico's long-term plans and projects to continue fostering industrial digital transformation.

ProMéxico cordially invites the readers to consult the many strategic documents about Mexico prepared by ProMéxico's Business Intelligence Unit and available on our website under Mexico's Investment Map (MIM) —on mim.promexico.gob.mx—, a website where investors can further explore Mexico as an attractive destination to do business. We also encourage you to consider the information presented there not only as a series of facts and data but also as good reasons to trust Mexico to be your ally in innovation.

PART 1
INDUSTRIAL COMPETITIVENESS OUTLOOK

By Jair E. Cabrera Padilla

1.1 MEXICO'S INDUSTRIAL LANDSCAPE

1.1.1 A PLACE OF OPPORTUNITIES

For over 10 years, ProMéxico has been promoting Mexico as a country of business opportunities, emphasising its strengths. The information included in this chapter is part of a collection of more than 100 infographics about Mexico's capacities to attract investment and innovation.

Source: CIA World Factbook

With a population of over 123 million, Mexico is the largest Spanish-speaking market in the world. Its capital city alone —Mexico City, plus its greater area— has 21 million inhabitants and is the economic, political, and cultural heart of the nation. Moreover, it is the world's 14th largest country, covering a surface of 1.96 million square kilometers.

With a productive capacity of a little over 1 billion USD (946,065 million euros), Mexico is the second largest economy in Latin America, and the 15th largest in the world. Its most important economic activities are manufacturing, retail trade, real estate services, infrastructure, and logistics.

One of the main drivers for business opportunities is the broad network of free trade agreements Mexico has signed with 46 partner countries. This network has opened the door to several products either manufactured or designed in Mexico to markets that, according to the International Monetary Fund, represent 60% of the world's gross domestic product (GDP), and to over a billion potential customers, mainly in America, Europe, and Asia. Some of Mexico's main exported goods are: light vehicles, auto parts and accessories, lorries, mobile phones and equipment, computers and

components, electric conductors, flat screen televisions, and medical devices. Thus, according to the Ministry of Economy (SE), in 2016 Mexico became the world's 13th largest exporter, reaching 374 billion USD in total exports.

Infrastructure is another driver. According to the Ministry of Communications and Transportation (SCT), Mexico has a vast road and railway network connecting the country's main industrial and business centers. This network runs across almost the whole country: from coast to coast, and from the northern border with the United States to the southern border with Guatemala and Belize —with 62 land border crossings, 54 only in the North.

Likewise, Mexico has multiple entry and exit points for both people and goods across its territory. The country has 68 international seaports with an ever-expanding loading capacity. With a total of 76 operating airports —64 of which operate international flights—, and the new airport in Mexico City (currently under construction and one of the most ambitious infrastructure projects of the century), Mexico is more open to the world than ever.

Source: Ministry of Communications and Transportation, 2017.

Source: Ministry of Communications and Transportation, 2017.

Source: Ministry of Communications and Transportation, 2017.

Source: Ministry of Communications and Transportation, 2017.

Last, but not least, human talent in Mexico is a key resource to establish and grow businesses for the development and implementation of innovative technologies. The most recent data by the National Association of Universities and Higher Education Institutions (ANUIES) point out that every year approximately 223,000 students graduate from science, technology, engineering, and mathematics (STEM) careers, a number that increases yearly. In fact, according to the World Economic Forum, in 2015, Mexico ranked 8th among the countries with more graduates in engineering, manufacturing, and construction. Today, Mexico has more engineering students than any other Latin American country and three times as many graduates per capita in this field than the United States. Higher education institutions in Mexico, both public and private, offer programs addressing the country's industrial needs and requirements. In addition, there are over 98 research and development centers focused on industrial innovation and advanced manufacturing in the country, and each of them has joint research projects with the industry in order to secure training continuity.

These comparative and competitive advantages represent an unprecedented window of opportunity. Today, investing in Mexico is a synonym of being part of the development and expansion of an industry based on innovation and high added value.

1.1.2 ADVANCED MANUFACTURING: A KEY INDUSTRY AND ITS STRATEGIC SECTORS

Manufacturing industry is Mexico's main economic activity. In 2016, the National Institute of Statistics and Geography (INEGI) found that manufacturing industry accounts for 18% of the country's GDP, followed by retail trade (16%), and real estate (11%). Not only has this industry enjoyed sustained growth during the last decade, it has now become one of the country's largest-growing sectors: between 2014 and 2016, manufacturing production increased by 17.83%, surpassed only by the hospitality industry (18.76%), and agriculture, livestock, and fisheries (18.5%). To a large extent, the secondary activity has become one of the country's economic drivers thanks to its focus on exports.

Currently, Mexico is consolidating itself as a manufacturing export power and a world-class manufacturing platform at competitive costs. Even during the global economic crisis, Mexico continued to be the leading exporter in Latin America. In 2009, the volume of Mexican manufacturing exports amounted to 104 billion USD, while that year's total exports were 230 billion USD. Since then, the country has continued developing and consolidating a highly dynamic productive ecosystem that not only emphasizes manufacturing, but also promotes product design. Close collaboration between players of the triple helix (government, private sector, and academia), the country's vast infrastructure and its free trade agreements network, the availability of qualified talent, together with investment in strategic sectors, have resulted in 80% of Mexican exports to be of advanced manufactures. This is even more notorious considering that according to the Organization for Economic Co-operation and Development (OECD), the Index of Technological Sophistication of goods produced in Mexico (3.25) is higher than that of countries like India (2.61) or Brazil (2.49).

The following table shows Mexico's 10 main exported products, 9 of which are manufactures that require a high degree of technological sophistication in their elaboration.

Top ten exported products from Mexico (as a share of total exports)	
Light vehicles	8.4%
Auto parts and accessories	7%
Trucks	6.3%
Smartphones and communications equipment	5.5%
Computers and related components	4.9%
Electric conductors	4.4%
Flat screen TVs	3.6%
Medical and surgical instruments	3%
Tractors	1.8%
Furniture and parts	1.5%

Source: Ministry of Economy, 2017

These advanced manufactures exports reflect Mexico's current mindset based on strengthening innovation capabilities to develop Mexican brands, product design, supply chain and productivity, with a long-term scope. Unlike traditional manufacturing, advanced manufacturing is an industry concerned with the skills and creativity to manufacture complex, high specification products. It does not exist as a set of separate businesses, rather as a network made up of engineers, business developers, entrepreneurs, scientists, financial and other experienced professionals who collaborate and pool their creative potential around innovative solutions for users and customers. In the case of Mexico, the advanced design and manufacturing industries have some prominent success stories.

Some of these cases are listed below and throughout this document:

- Tremec transmissions designed for Corvette, Mustang and Hummer.
- Ram trucks chassis designed and manufactured by Metalsa.
- Minnesota train designed and manufactured by Mexican engineers at Bombardier.
- Mastretta, sports car designed in Mexico.
- 787 Dreamliner interiors designed by Zodiac Mexico.
- Low pressure turbines at ITR.
- New Jetta bicentennial edition with 70 percent of its parts by Mexican suppliers, whose design and development involved over 900 Mexican engineers.
- FX-05 "Xiuhcoatl" assault rifle designed and conceived by more than 64 military engineers from the Military Industry Center for Applied Research and Technological Development (CIADTIM).
- The design of the Salamandra Lexion car for the Spanish company Yakey, conceived in Mexico, featuring a compressed air engine (top speed of 55 mph) and a hybrid version (combustion engine and compressed air) capable of speeds approaching 90 mph.
- Zonda Telecom, a 100-percent Mexican company that has been designing mobile phones since 2002, with a presence in more than 11 countries in Central and South America.
- GX turbine designed by GE and more than 120 engineers. The company was also involved in the creation of Airbuss 380, the world's biggest aircraft, turbine.

Most of these products designed and manufactured in Mexico, usually destined for export, can be manufactured thanks to the country's reputation for safe investments. Year on year, Mexico has attracted significant volumes of foreign direct investment (FDI) for manufacturing activities: of 26.74 billion USD of FDI recorded in 2016 by the Bank of Mexico and the SE, 48% pertain to the manufacturing industry —followed by services with 15%—, making it the economic activity with the most investment. Some of the main sectors of destination are key for the Mexican economy, like the automotive industry, which that same year received 4.851 billion USD, followed by metal-mechanics (1.784 billion USD), electronics (997.9 billion USD), medical devices (211.4 billion USD), and aerospace (207.6 billion USD). In the following sections, key data —such as performance, exports, investment, employment, and projects— about six strategic sectors that conform the Mexican advanced manufacturing industry is presented.

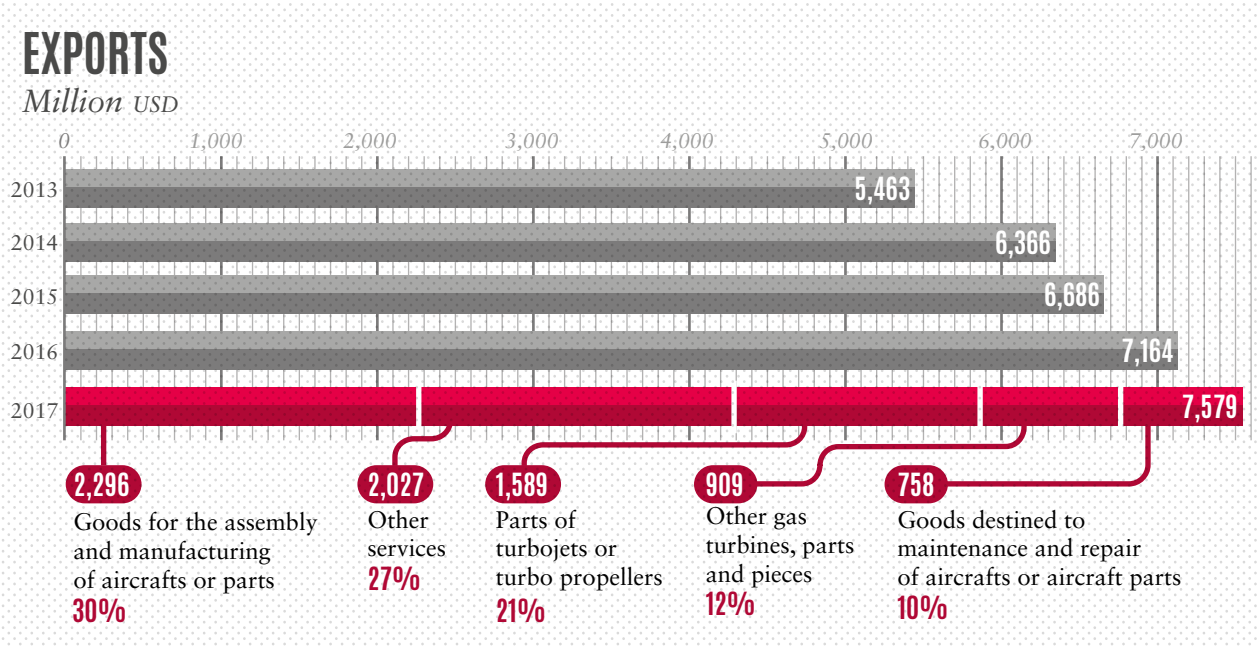
Aerospace

Current Situation

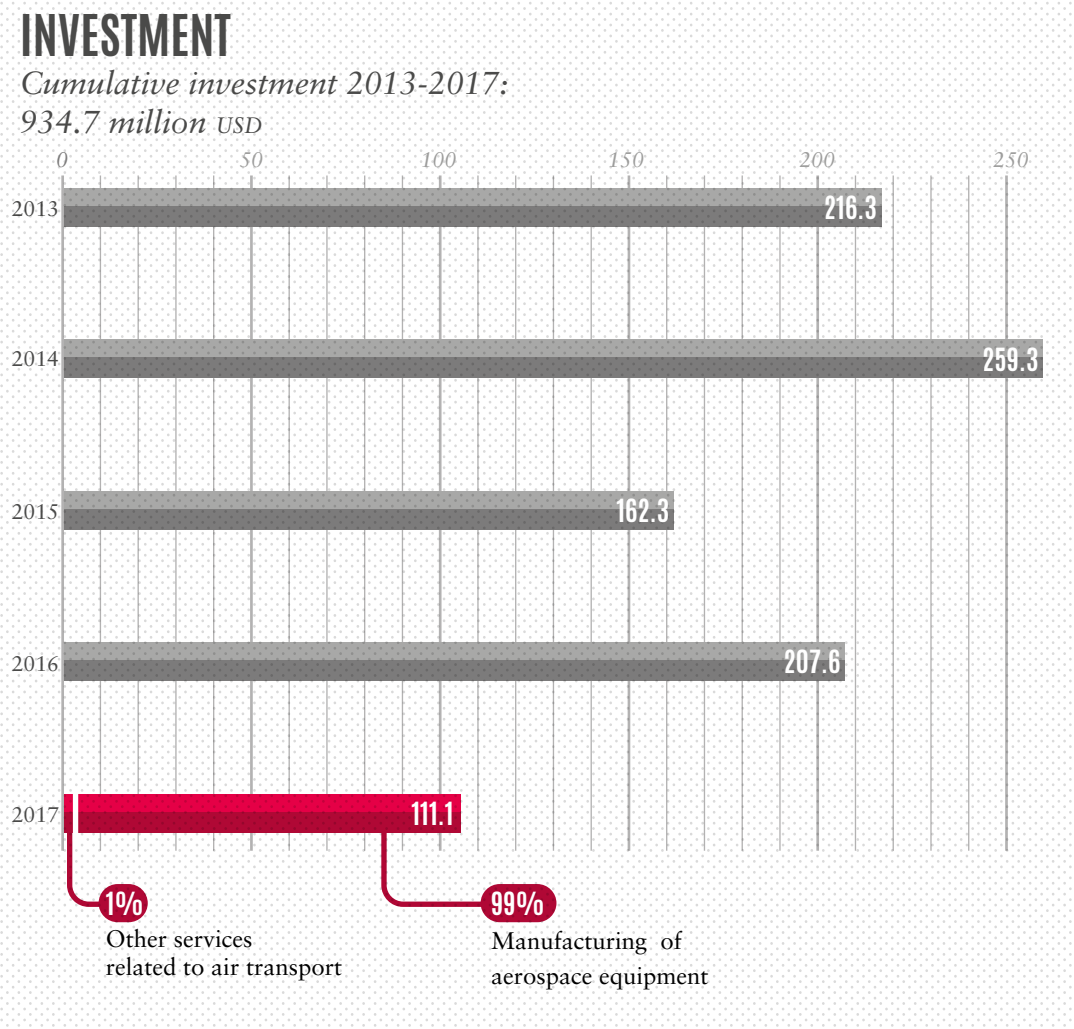
The aerospace sector is one of the most recently developed and fastest-growing in Mexico. According to estimates from the 2010-2020 Aerospace Industry Strategic Program, coordinated by SE, this sector will report exports for 12,267 billion USD by 2021, with an average annual growth rate of 14%. Currently, there are 330 certified aerospace support agencies and companies operating in the country. In the last two decades, global companies like Bombardier, Safran Group, General Electric, UTC Aerospace, Eurocopter, Textron Group (Cessna-Bell Helicopters-Beechcraft), Airbus Helicopters, and Honeywell have set up offices in Mexico, mainly in six states: Querétaro, Chihuahua, Baja California, Nuevo León, Sonora, and Guanajuato.

Mexico has an ecosystem with advantageous conditions to develop design and engineering centers, laboratories and production lines capable of evolving quickly to handle more complex assignments in the race for next generation engines and airframe components and, most importantly, it protects intellectual property. Private companies have collaborated with the public sector to create important research and development (R&D) centers —for example, General Electric's GEIQ, in Querétaro, and Honeywell's Mexicali Research and Technology Center (MRTC), in Baja California. Also, the SE and ANUIES estimate that a total of 50,000 people work in the sector, and that every year 178,000 graduates from related academic programs are ready to join them.

The sector's dynamism is reflected in the constant growth of its exports and investment: between 2013 and 2017, the sector's exports have had a steady annual average growth of 9%, and investments amount to an average of 211.4 billion USD per year. Thus, Mexico has become the United States' 7th supplier of aeronautical parts, outstripping China, Korea, Singapore, and Italy. The following graphs show the yearly volume of exports and investment, as well as the sector's most exported products in 2017.



Source: INEGI, 2017.



Source: National Registry of Foreign Investments (RNIE) of the Ministry of Economy, 2017.

Strategic Projects and Players

In Mexico, aerospace R&D is booming, especially in new materials, turbines, and fuel. Companies like GE and Honeywell are conducting research in and designing new turbines —including the GenX turbine, which saves almost 15% in fuel and has a 30% lower carbon footprint, and which design tests were performed at the GEIQ in Querétaro, where the next generation LEAP-X Turbine R&D is also done. Moreover, institutions such as Aeropuertos y Servicios Auxiliares (ASA) and the National Council of Science and Technology (Conacyt), have fostered the creation of a sustainable aviation biofuel plant in the state of Chiapas.

Mexico also has several research centers and laboratories specialized in advanced materials and nanocompounds, including the Mexican Materials Research Corporation (Corporación Mexicana de Investigación en Materiales, COMIMSA), the Advanced Materials Research Center (Centro de Investigación en Materiales Avanzados, CIMAV), the Mexican Institute for Graphene (Instituto Mexicano del Grafeno, IMG), and the Materials Research Institute (Instituto de Investigaciones en Materiales, IIM). These centers enable new opportunities to develop state-of-the-art composite materials, like the graphene 17, a carbon fibre recently developed in Mexico that is 200 times stronger than steel and intended for the defense aerospace industry.

The availability of laboratories, highly-skilled human capital, certification units, and the involvement of Mexican civil aviation authorities have contributed greatly to the Bilateral Aviation Safety Agreement (BASA) with the United States Federal Aviation Administration. This agreement entails the recognition by the United States government of aeronautical certification systems and products made in Mexico, which allows components to be designed and manufactured in Mexico and encourages the strengthening of domestic and international supply chains.

A sub-industry that could significantly benefit from this agreement is that of unmanned air vehicles (UAV) or drones. Some companies in Mexico, like Hydra Technologies and Unmanned Systems Technology International (USTI), have focused on the development and manufacturing of these vehicles. By harnessing Mexico´s manufacturing capacity, research and development talent, and dual-use international technology, it is possible to become a key supplier of the rapidly growing UAV North American market from Mexico.

Last, but not least, the Mexican space sector is characterized by its increasing number of synergies. Mexican companies from this sub-sector have bolstered the Mexican Space Initiative (MX-Space) and have worked closely with the Mexican Space Agency (AEM) to align the industry's interests with those of the country through comprehensive projects. Within these initiatives, there are projects like a private laboratory dedicated to developing payloads, operated by Ai Systems in Chihuahua; a Simple Complexity operation in Ensenada, Baja California, to manufacture Printed Circuit Boards (PCBs) to be used in space; the development of femto satellites by Thumbsat of Mexico; the development of small-lift launchers by Ketertech and Datiotec, and Latitud 19:36's work developing ground segment capacities and infrastructure.

Automotive

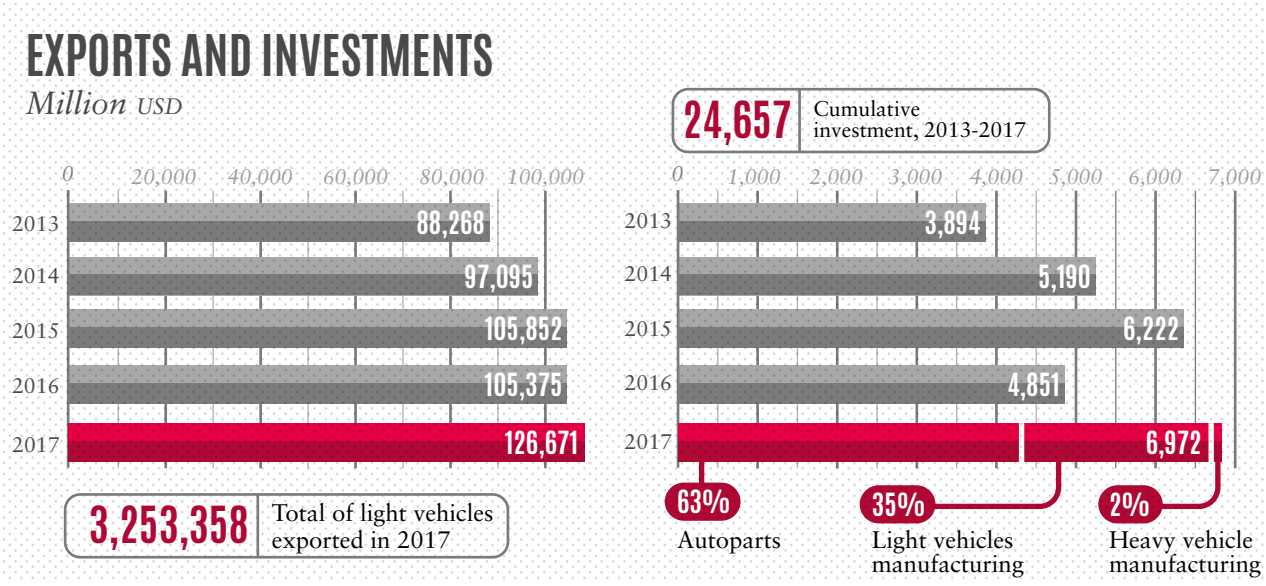
Current Situation

The automotive sector is one of the pillars of the Mexican manufacturing industry. Nowadays Mexico is among the world's 10 major producers of automobiles, lorries, auto parts, and components. Although its main export market continues to be the United States, in recent years, there has been an increase in exports to other regions, especially to the European Union and Latin America.

In Mexico, there are 24 assembly plants and at least 2,500 Tier 1 and Tier 2 companies designing and manufacturing auto parts —90 of which are among the world's 100 most important auto part companies. Although currently in Mexico the integration of imported systems and subassembly parts outweighs the manufacture of products and components, the sector is increasing its national suppliers' competitiveness through the creation of research and development centers. So much so that there are now 30 R&D centers in the country, supporting companies with certifications, quality control tests, training, prototyping and, above all, constantly innovating both in processes and in materials. Thus, and according to the INEGI, the automotive sector represents 18% of the manufacturing GDP and employs nearly 800 thousand people.

Mexico offers a sophisticated assembly capacity, which includes product research and design that complies with the highest international quality standards. The Mexican Automotive Industry Association (AMIA) found that the sector stood out in 2016 thanks to the finished-product manufacturing of 3.5 million light vehicles, 2.5 million of which were exported. Thus, for example, in 2015, Nissan's plant in Aguascalientes, managed to remain third out of the five main manufacturing plants in North America.

Given Mexico's attractiveness to new investments and expansion programs, it is expected that the sector reaches a productive capacity of 5 million vehicles by 2020. Currently, Mexico is the world's 7th producer and 4th exporter of light vehicles. However, it is worth mentioning that four states: Sonora, Coahuila, Puebla and Estado de México, account for half of the national production and exports. The following graphs show the exports and investment volumes for the period 2013-2017, and the disaggregation for the main products.



Source: National Registry of Foreign Investments (RNIE) of the Ministry of Economy, 2017.

Strategic Projects and Players

Companies from the light vehicle finished-product industry, like Nissan, Ford, Toyota, Honda, General Motors, KIA, Mercedes-Benz, Mazda, Ford, Audi, Fiat Chrysler Automotive, Infiniti, and Volkswagen, have a total of 24 manufacturing plants in 14 states, where they perform activities ranging from assembly and armouring to foundry and stamping of vehicles and engines. Currently, over 50 models of cars and light lorries are manufactured in Mexico; 16 of which are manufactured with the sole purpose of selling them in the American market.

Mexican innovation has helped launch better products that make the renown automotive sector more competitive in the domestic and international markets. For example, two of the engine models manufactured exclusively in Mexico have been ranked among the "Top 10 best engines of 2015" by Ward's Automotive.

- Volkswagen's TSI Turbocharged 1.8 liter engine, assembled in Silao's plant in Guanajuato, is used in Jetta, Beetle, and Passat car models.
- The supercharged 6.2 liter OHV Hemi V8 engine, assembled in Saltillo, in the State of Coahuila, is used in the Dodge Charger SRT Hellcat models.

In addition, Mexico won the "North American Car of the Year" award at the 2015 Detroit Auto Show, beating Mustang and Hyundai Genesis:

- The GTI Golf, manufactured in Puebla.

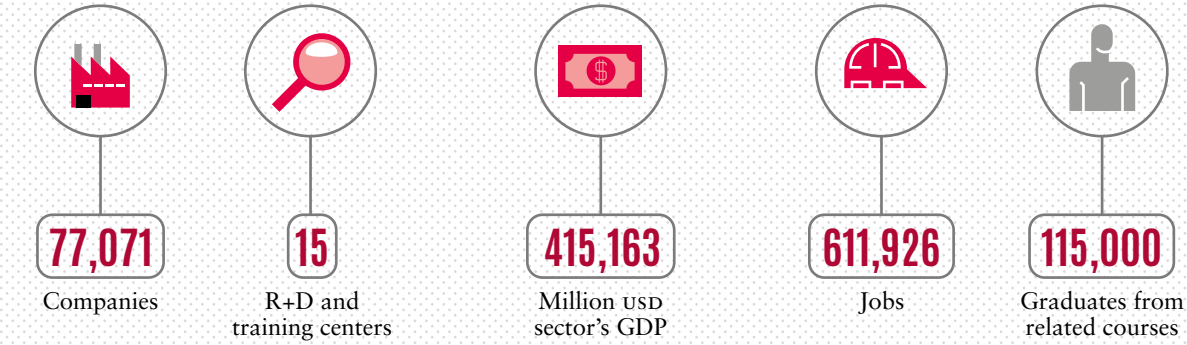
On the other hand, heavy-vehicles manufacturers like Dina, Hino, Volkswagen, Izuzu, Scania, Giant, Hyundai, Daimler, International, Kenworth, and Volvo, design and assembly a wide range of models and components to satisfy the demand of the domestic and export markets. Currently, these heavy-vehicle have manufacturing plants in eight states: Nuevo León, Guanajuato, Querétaro, Chihuahua, Puebla, Aguascalientes, Coahuila, and Sonora.

Given the global disruptive transformation of the automotive sector, thanks to the fast-paced technological changes to produce cars that are more electrified, connected, and autonomous, Mexico seeks to implement the following three new trends in its strategic sector:

1. Increase the use of electronic components. Mexico has a mature electronics sector with a wide base of electric component manufacturers and developers, amounting to over 1,000 players mainly located in the northern border and the State of Jalisco. A closer link with this sector could yield considerable benefits for the automotive sector assemblers in developing and manufacturing new technologies and components demanded by the production of electric vehicles.
2. Incorporate dvanced materials to build the car of the future. The more than 98 centers of research and development working in advanced manufacture in Mexico, are involved in collaborative projects with some companies to perfect and develop new materials. At the same time, the country's auto part supply chain is already beginning to offer products for the cars of the future. For example, the Mexican company Nemak that manufactures super-light aluminum structure components already supplies the Chinese electric cars manufacturing market.
3. Develop operational configuration and customization software. It is expected that, in the future, most of the automotive industry turnover will come from this type of activities. Therefore, it is vital to make the most of Mexico's highly skilled and specialized IT labor force, which is one of the main service producers and exporters in the American continent. It is here where Mexican IT suppliers have a great opportunity to offer their services and solutions.

Metal-mechanic

The metal-mechanic industry is a key link of the industrial supply chain, since it produces finished products and components for all the other sectors, especially aerospace and automotive; for this reason, it plays a key role in the Mexican economy and is known as an "industry of industries". In fact, it is one of the oldest sectors of the economy, since it has been manufacturing cars, durable consumer goods, and farming equipment since the 1950's, which has allowed it to accumulate certain technological capacities. Following are some key data for this sector:



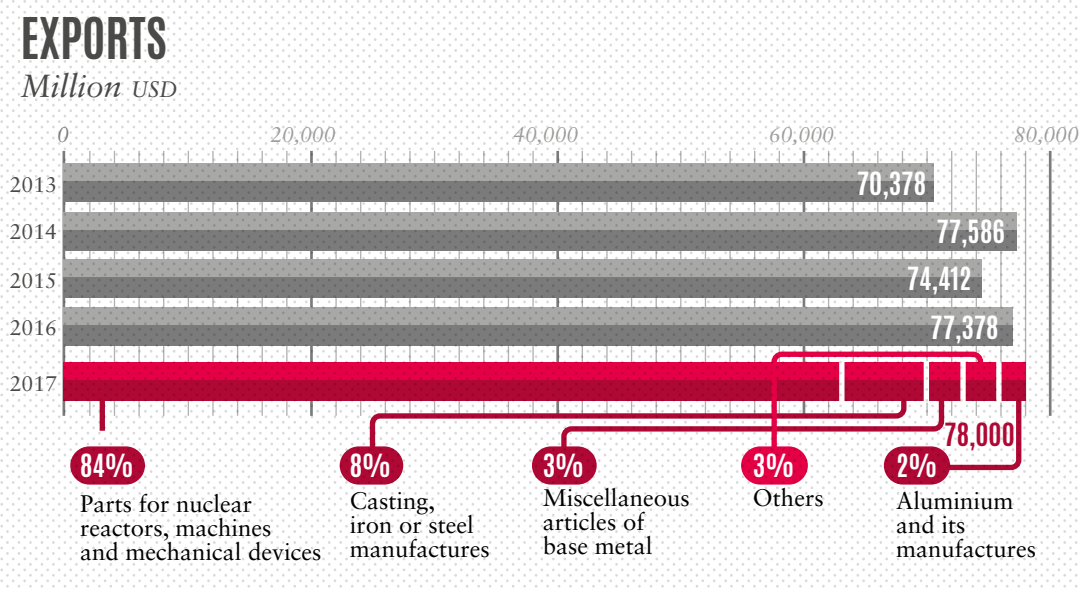
Source: INEGI, 2017; Integrated Information System of Scientific and Technology Research (SIICYT), 2016; Bank of Mexico, 2016; SE, 2016; ANUIES, 2015.

MAIN COMPANIES AND ASSOCIATIONS

Source: INEGI, 2017; Integrated Information System of Scientific and Technology Research (SIICYT), 2016; Bank of Mexico, 2016; SE, 2016; ANUIES, 2015.

According to the National Chamber of the Transformation Industry (CANACINTRA), metal-mechanics represents about 16% of the Latin American industrial GDP, generating 4.1 million direct jobs, and 19.7 million indirect jobs. However, Latin America has faced two major challenges: on the one hand, the opening of global markets, and on the other, the growing role of countries like China as global competitors, which has led to a deindustrialization process. Despite this, Mexico has continued to be one of the main global exporters of mechanical machines, devices, and artefacts. Aluminum, iron, steel and other common metal manufactures account for most of its sales, making of Mexico an attractive country for foreign investment, surpassing the 3 billion USD in the period 2016-2017.

According to a study published by the Ministry of Economy and CANACINTRA, the domestic metal-mechanic sector is currently facing several challenges in terms of productivity and competitiveness, as company types are becoming polarized. On the one hand, there are big companies that are highly integrated to global value chains but have no integration with the local industry. On the other hand, there are the smaller and micro companies, operating without a corporate strategy, with a solely local focus, and without alliances or strong elements to compete successfully in highly competitive markets. These are some of the main exports from the sector:



Source: TradeMap, 2017.

Despite this, Mexico has managed to successfully penetrate global markets and participate in the trade opening thanks to a consolidation of qualified human resources. Mexican human talent —a generation of engineers and technicians trained in metal-mechanic technologies— stands out in metal-mechanic activities like welding, stamping, forging, and designing. Thus, Mexican human talent is the main resource Mexico can offer the new technological industries in order to maintain its international competitiveness.

Strategic strengths and actions

Mexico has started to dabble in research, development and innovation (R&D&i), both in productive processes and in the development of final products. Mexican businesses' vision in this sector is focused on strengthening their innovation systems, for which they already have the human talent they need. Although it is true that most technology currently used is imported, Mexico's policy is to attract investment, favoring those that foster technology and knowledge transfer to Mexican companies.

The continued growth of global competition has led many companies from the metal-mechanic sector to implement programs to improve their competitive position, as this sector is not specialized in any specific product or service. Thus, they may seek to integrate into global value chains where they can import raw material, and cutting-edge equipment and machinery, and export products with a higher degree of sophistication. At the moment, Mexican companies in the metal-mechanics sector have the capacity to increase their production, as many of them are working at less than 50% of their installed capacity. This means that Mexican and foreign partners can find business opportunities in different industries.

One of the recurrent Mexican priorities is intensifying the training and certifications of the workforce in cutting-edge industrial processes and technologies. This is a significant challenge, given the diversity of the industry. For example, having been used in the manufacturing industry for such a long time, forging is one of the most valuable processes for Mexico. It was originally used to make jewelery, coins, and hand tools. Nowadays, however, forged parts are used in automotive components, turbine rotors, gears, lug nuts, valve components, and machine parts, among others.

There are business opportunities in this and other metal-mechanic processes, thanks to the fact that established companies have grown strong in areas like quality management, experienced staff, good customer service, solid infrastructure, and flexible production. Consequently, ProMéxico created a national capacities map, with information about the main companies in the sector, as well as the different forging processes they use, the materials they process, their production infrastructure, their quality assurance tools and certificates, their customers and development plans, and more. This document and others are available on ProMéxico's Investment Map Website.


83
167
69
33
14
15
97
83
SpO2
120
80
CNAP
100

Medical Devices

Current Situation

In Mexico, the medical devices sector is relatively young, and is composed mainly of small and medium enterprises. However, it has shown to be successful in design and assembly processes, having potential to develop more advanced technological frames, and a higher level of integration with the productive chains.

Mexican medical devices sector production reached 12.7 billion USD in 2017, with domestic sales valued in 2.6 billion USD and exports close to 10 billion USD, according to data provided by Information Handling Services Markit (IHS Markit). Global corporations like Medtronic, Johnson & Johnson, General Electric, Siemens, Becton Dickinson, Cardinal Health, Philips, and Baxter coexist in the market together with other 2,300 domestic and international companies that manufacture from needles, catheters, cannulas, and similar medical, dental and lab instruments to more technologically complex products like mechanotherapy, medical assessments, massages, oxygen therapy, and aerosol therapy. The main producer states are Baja California, Chihuahua, Coahuila, Mexico, Jalisco, Nuevo León, Sonora, Tamaulipas, and Mexico City.

The sector's performance is outstanding, with exports showing an annual average increase of 9%, while investment has maintained at approximately 166 million USD. It is worth mentioning that over 65% of the investment goes to the production of electronic medical equipment. The multiple advantages offered by Mexico to produce and export these products have made of the country the world's 8th exporter and the main medical device provider for the North American market. The following graphs show exports' value, as well as investments for the period 2013-2017, including information on the value of exports of the main products for last year.

Strategic Projects and Players

Compared to other manufactures, this sector has unique characteristics. For example, medical devices are subject to specific, strict regulations by the Federal Commission for Sanitary Risks (COFEPRIS), Mexico's sanitary authority. These products have to be manufactured in 'clean rooms' to guarantee their sterility. Also, manufacturing plants are subject to inspection by domestic and international sanitary authorities; such as the World Health Organization, while periodically conducting clinical trials on products to demonstrate their quality and efficacy.

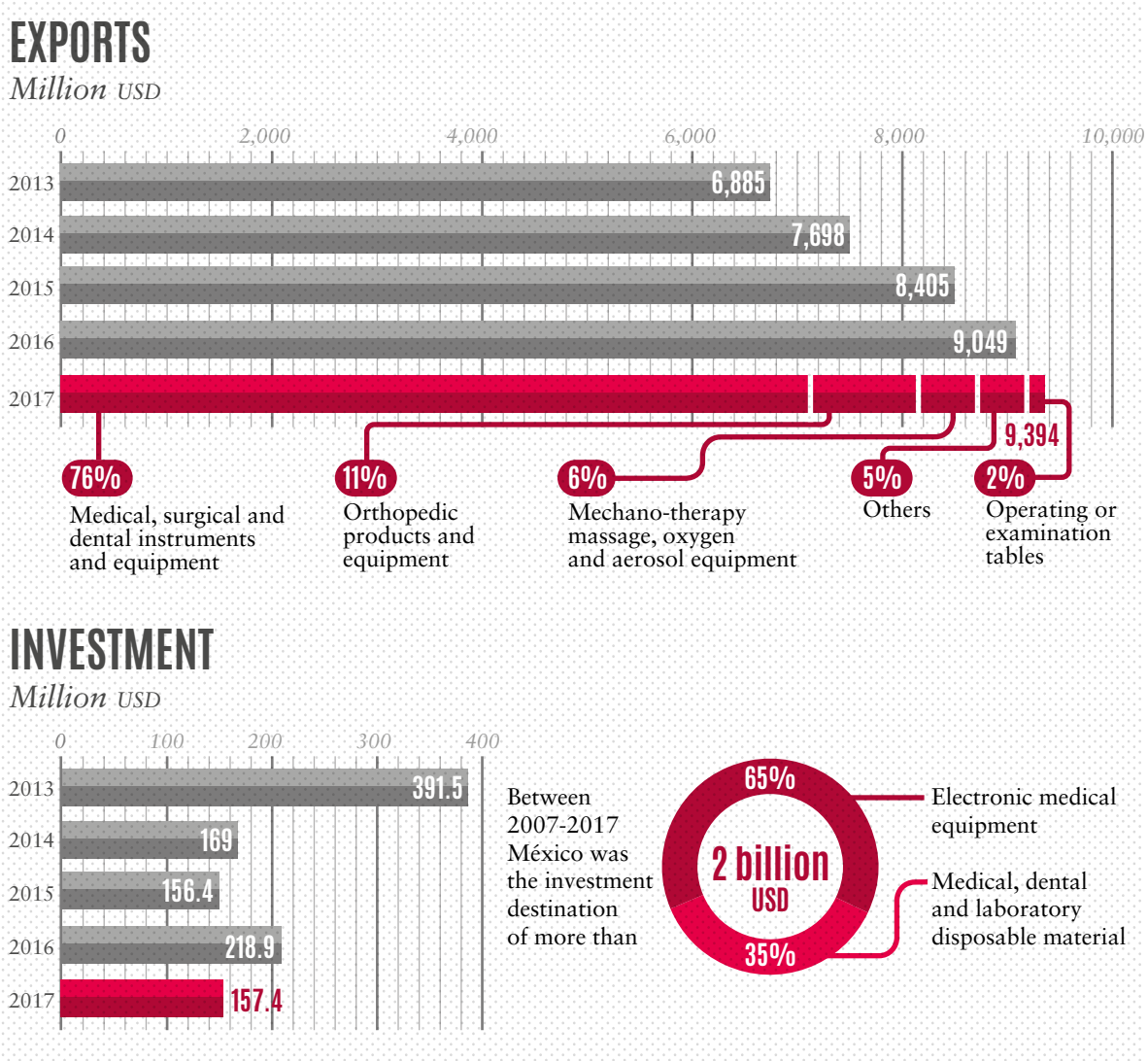
The high technology product segment, that produces sophisticated devices designed exclusively for therapeutic and diagnostic treatments, has great growth potential in Mexico. Sectors that are already developed in the country, such as electronics, biotechnology and nanotechnology, provide new materials, test analysis, prototyping, and new product design using scientific and technologically based iterative enhancements. It is worth highlighting the Mexican-American Medical Devices Initiative (Iniciativa en Dispositivos Médicos México- Estados Unidos) by the Mexican-American Foundation for Science (FUMEC). This initiative's main goal is to support Mexican product developers through TechBA, connecting them with foreign corporations and clusters (like Silicon Valley), where companies seek low cost manufactures. Thus, Tijuana —a city on border with San Diego, California— has become Mexico's main medical devices manufacturing center.

The main innovation projects in the Mexican medical device sector are focused on software, IT and communications, hardware design, and engineering of medical and biotechnological applications. Organisations such as the Monterrey Institute of Technology & Higher Education (ITESM), the National Institute of Astrophysics, Optics and Electronics (INAOE), the Autonomous University of Nuevo León (UANL), the Center of Applied Chemistry Research (CIQA), and the Yucatán Center of Scientific Research (CICY) are developing significant capacities in device design and development for illness detection and diagnosis, as well as information systems for health institutions. Some examples of their projects are:

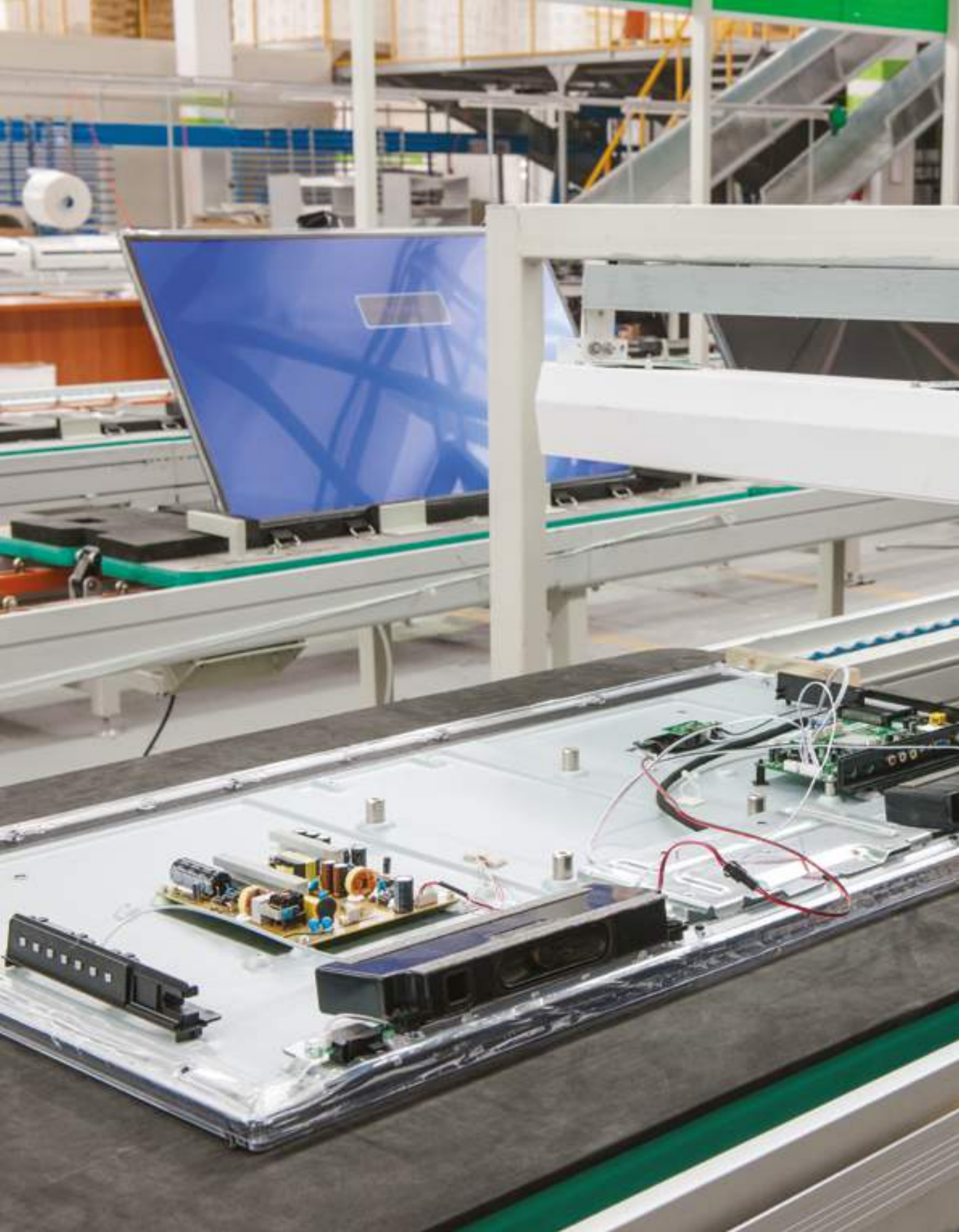
- Technology for the automated, computerized-assisted detection of leukemia and cervical cancer developed by the INAOE and based on the morphological analysis of medullary bones imaging. This technology has been transferred to the country's two main health institutions:

The Mexican Institute of Social Insurance (IMSS) and the Social Security and Services Institute for State Workers (ISSSTE).

- Micro-electro-mechanic systems (MEMS) for telecommunications and biomedical applications developed by the ITESM.
- Microstructural influence on biocompatible surfaces in surgical implants' tribological behavior by the UANL.
- New materials (mainly polymers) for biomedical applications developed by the CIQA and the CICY.



Source: TradeMap, 2017; RNIE, 2017.



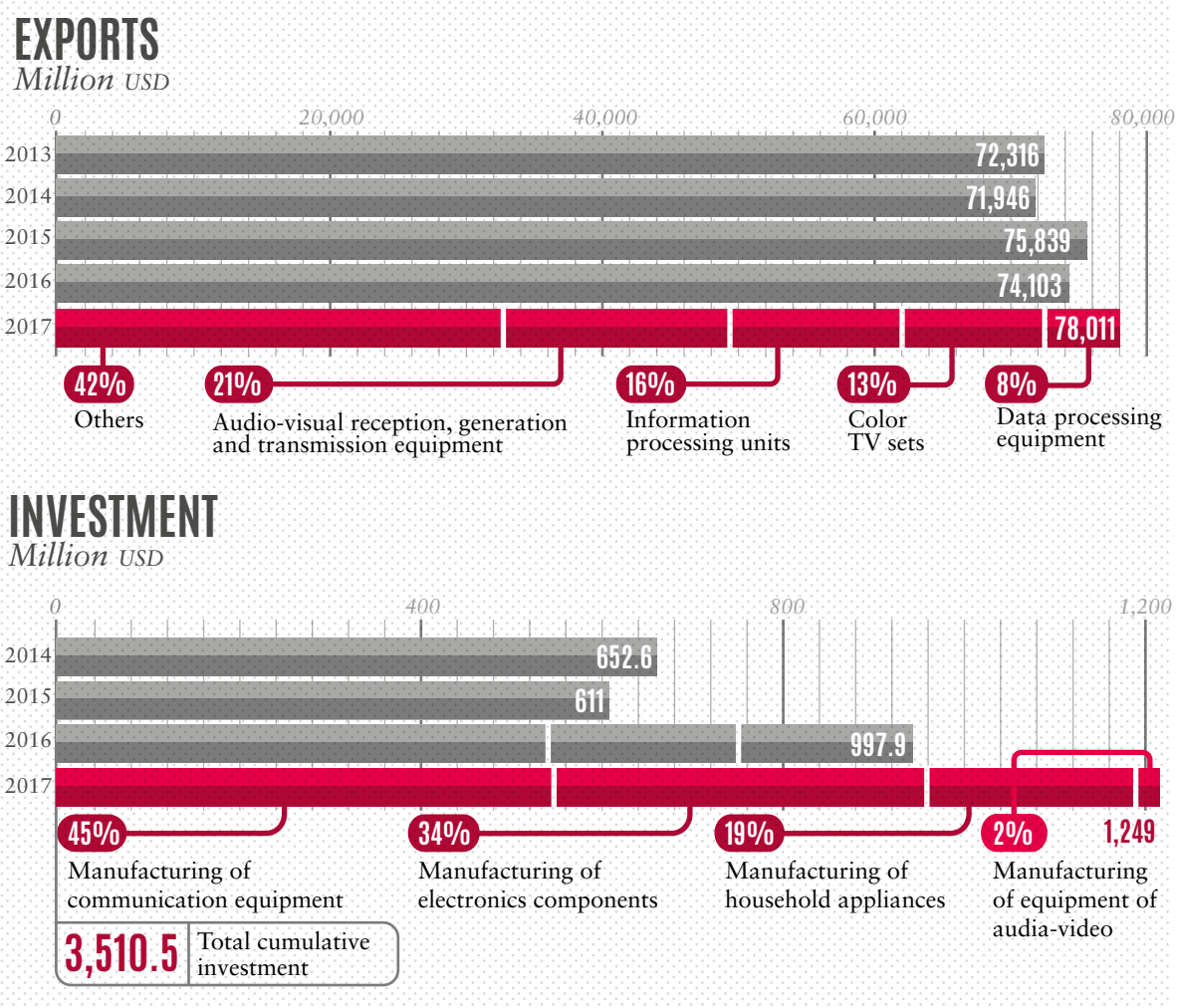
Electronics

Current Situation

Of all the sectors mentioned so far, electronics is one of the most mature sectors in Mexico, as it grew largely after the North American Free Trade Agreement was signed in 1994. Currently, there are over 1,000 companies operating in Mexico; such as, Huawei, Samsung, Nokia, Mabe, Siemens, Philips, Foxconn, Elcoteq, Daewoo, Panasonic, and General Electric, which jointly employ over 300 thousand people. Nine out of the ten main transnational electronic manufactures, such Flextronics, Jabil Circuit, Celestica and Sanmina SCI, operate in the country.

According to Global Insight estimates, electronics production in Mexico will continue to grow at an average annual rate of 4.6%, while consumption will reach 5.1% by 2020. The sector's exports are at an annual average of around 74 billion USD. Although investment fluctuates yearly, IHS Markit estimates indicate that the country continues to be the 8th largest world electronic producer, the 2nd largest flat screen exporter, and the third largest exporter of computers.

Below, there is information on the volume of exports and the value of the industry's main products in the last available year; and on FDI by main destination products for the 2013 to July 2017 total aggregate.



Source: Trade Map, 2017; RNIE, 2017.

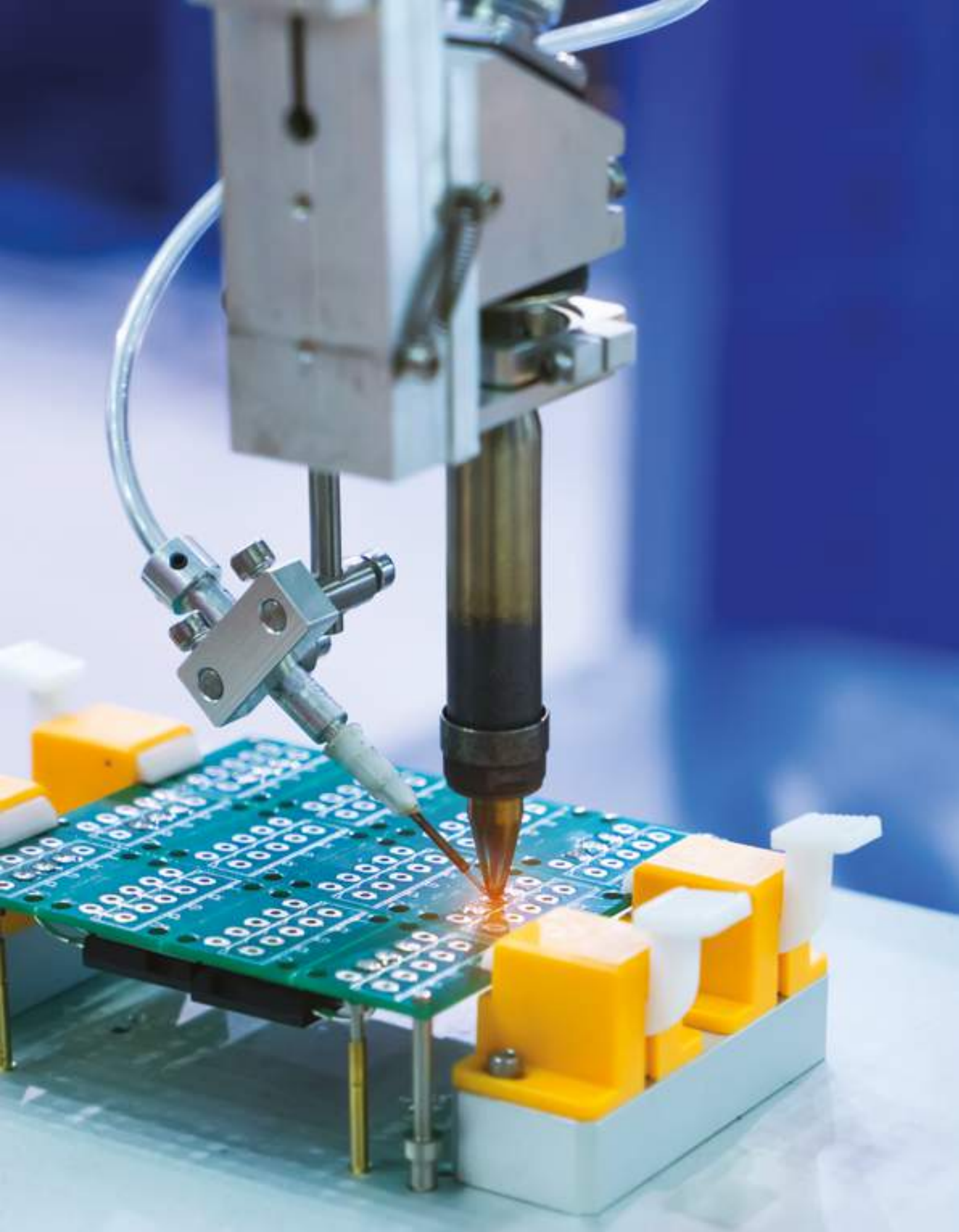
Strategic Improvements

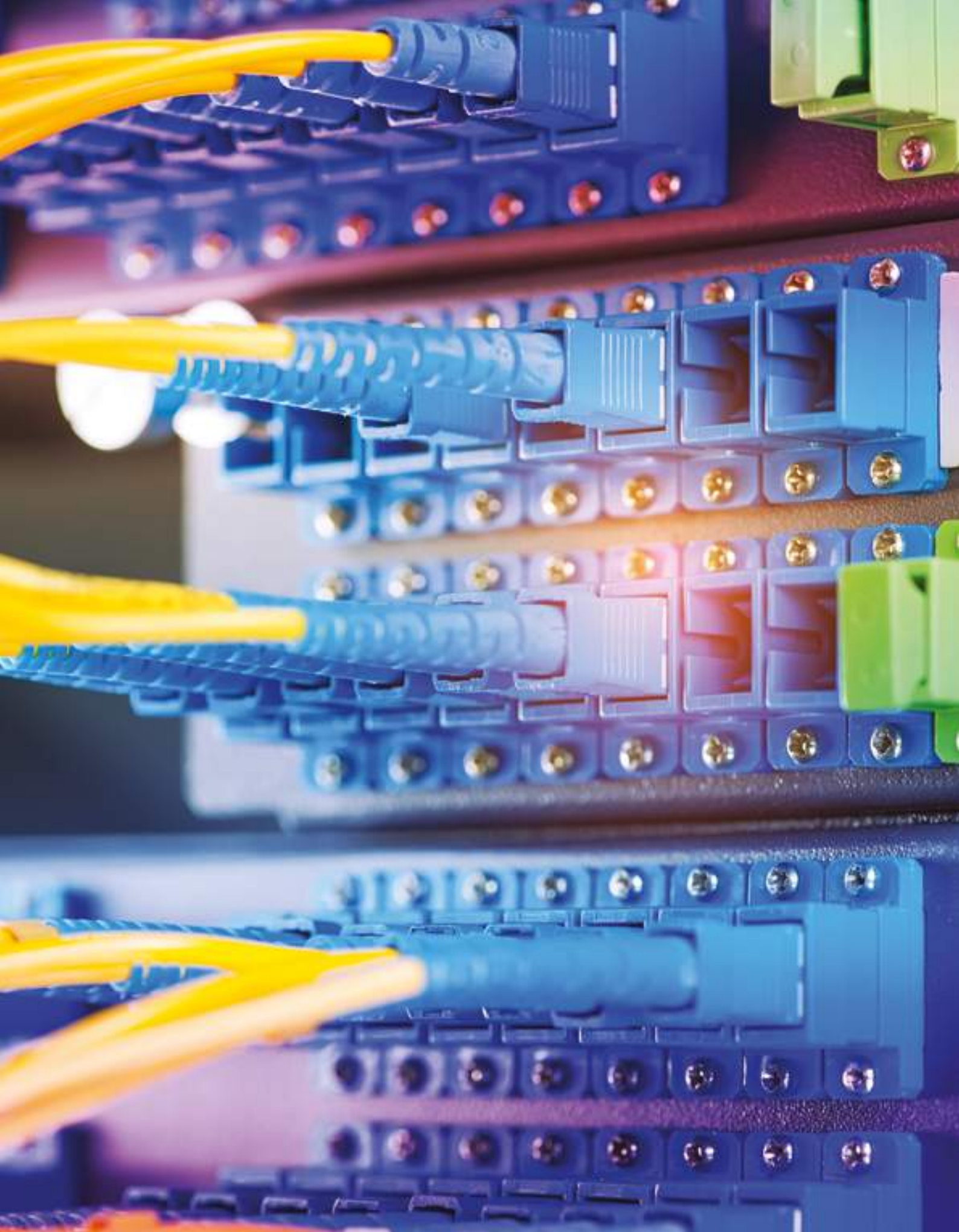
In electronics, compared to other globalized sectors like automotive or aerospace, innovation is highly dynamic. The fast introduction of new product models and the obsolescence of others, as well as the establishment, merging, and closure of companies, force the productive chain to reorganise frequently, especially in intermediate and final product links. This is where Mexico currently participates with activities like assembly and testing, mechanical elements supply (plastic and metallic), packaging, as well as manufacturing support services (administrative, logistic, maintenance and repair, and human resources, among others).

To improve Mexico's position as a key link in the chain, performing activities related to developing electronic components (capacitors, diodes, resistors and semiconductors), product design, embedded software, distribution and marketing, and the IoT, the Mexican electronic sector is redirecting its focus towards electronics segments other than consumption, such as avionics, electro-medical, home automation, and telematics. Likewise, it is looking to establish links with chemical, advanced materials, and information technology industries. In addition, Mexico seeks to encourage the sectorial diversification of its supplier base, reviewing cases of captive companies or companies whose business portfolios' low diversification leave them at risk in the face of changes in demand or foreign acquisition. Certainly, the electronic sector is one of the most sensitive to the effects of global supply chains.

Aware of the need to foster the development of solutions for these new trends, Mexico is strengthening its capacities to implement high-value projects in three key elements that will determine the future of electronics:

1. Internet of Things (IoT). Objects interconnection will be one of the century's most important technological trends. According to experts, by 2019, home devices worth in 1.9 billion USD will be connected to the Internet, and Latin America is expected to experience its massification by the end of 2020. In this regard, and according to OECD data, Mexico leads the way and is expected to have 200 million connected devices by then; thus, becoming the most connected country in the region. As for statistics on the penetration of connected devices among the population, Mexico ranks 18 out of 24 countries considered by the OECD, with a total penetration of 6.3%. Currently, 30% of Mexican companies are taking actions to incorporate IoT to their business models. While the private sector is pushing hard for it, the Mexican government is reviewing its regulations to encourage the development of this technology.
2. Intellectual Property (IP) registration. IP is vital to the sector's competitiveness and specialisation, and a strong strategy to penetrate new markets. Hence, Mexico encourages international collaboration for the recognition of intellectual property, through methodologies and best practices exchange to obtain better assessments, which can, in turn, shed light on investors' intellectual property assets to develop new products and innovate.
3. The future of product development. Considering that production systems are undergoing a new industrial revolution, where technological improvements in robotics, artificial intelligence, Big Data analytics, and IoT will transform manufacturing and business models at unprecedented speed, electronics sector becomes a fundamental enabler. Mexico and the world are moving towards an economy that needs electronics to feed its systems and provide access to information, as well as to help to maximise emerging technologies that promote innovation in new product development.





Information Technology (IT)

Current Situation

Despite not performing proper manufacturing activities, IT produces extremely important products and services for the manufacturing sector and other Mexican industries. Mexico is the 3rd largest exporter of Information and Communication Technology, accounting for 4.3% of the Mexican GDP, according to the Ministry of Economy.

Although most of the sector's activity is in communications, the sub-sector of Information Technologies (IT) is experiencing fast growth and great dynamism. These are the IT statistics for Mexico:

Indicator	2012	2016	Average Annual Growth Rate (2012-2016)
Economic Units	1,436	3,742	27.05%
Certified Development Centers	321	781	24.89%
Jobs	34,588	62,794	16.08%
Graduates (Engineering and Technology)	57,381	66,582	3.79%

Source: Roadmap for the IT sector in the State of Jalisco. ProMéxico, (2018).

Technology corporations like Microsoft, Google, Amazon, Facebook, Apple, Bosch, Dell, Intel, Luxsoft, HP, Persistent, and Algartech coexist with another 3,700 companies that offer electronic information processing and hosting services, computer system design, and software editing integrated to production. Some operate under BPO (Business Process Outsourcing) models, either 'nearshore' mainly for the North American market or 'offshore' for the rest of the world.

In Mexico, there are preferred state destinations such as Puerto Progreso in Yucatán, designated at the end of 2017 as a Special Economic Zone for science and information and communication technology; Nuevo León, which profits from being on the border with the United States and have developed successful concepts of 'Nearshore' services provision; and Jalisco, which is considered to have the country's main technological city: Guadalajara, whose metropolitan area has been dubbed 'the Mexican Silicon Valley'. These locations, especially the latter, are characterised by strengths such as IT-specialist human capital, educational institutions committed to the sector, collaboration of the triple helix, a growing start-ups landscape, a growing technological infrastructure, and, therefore, competitive costs for the provision of IT services.

Strategic Improvements

For Mexico, information technologies are the foundation for a general democratisation of innovation. Advancements in this sector are impacting on all other strategic sectors, redefining job positions and business models. Therefore, Mexico has outlined six guidelines to channel the sector's growth and development to foster innovation:

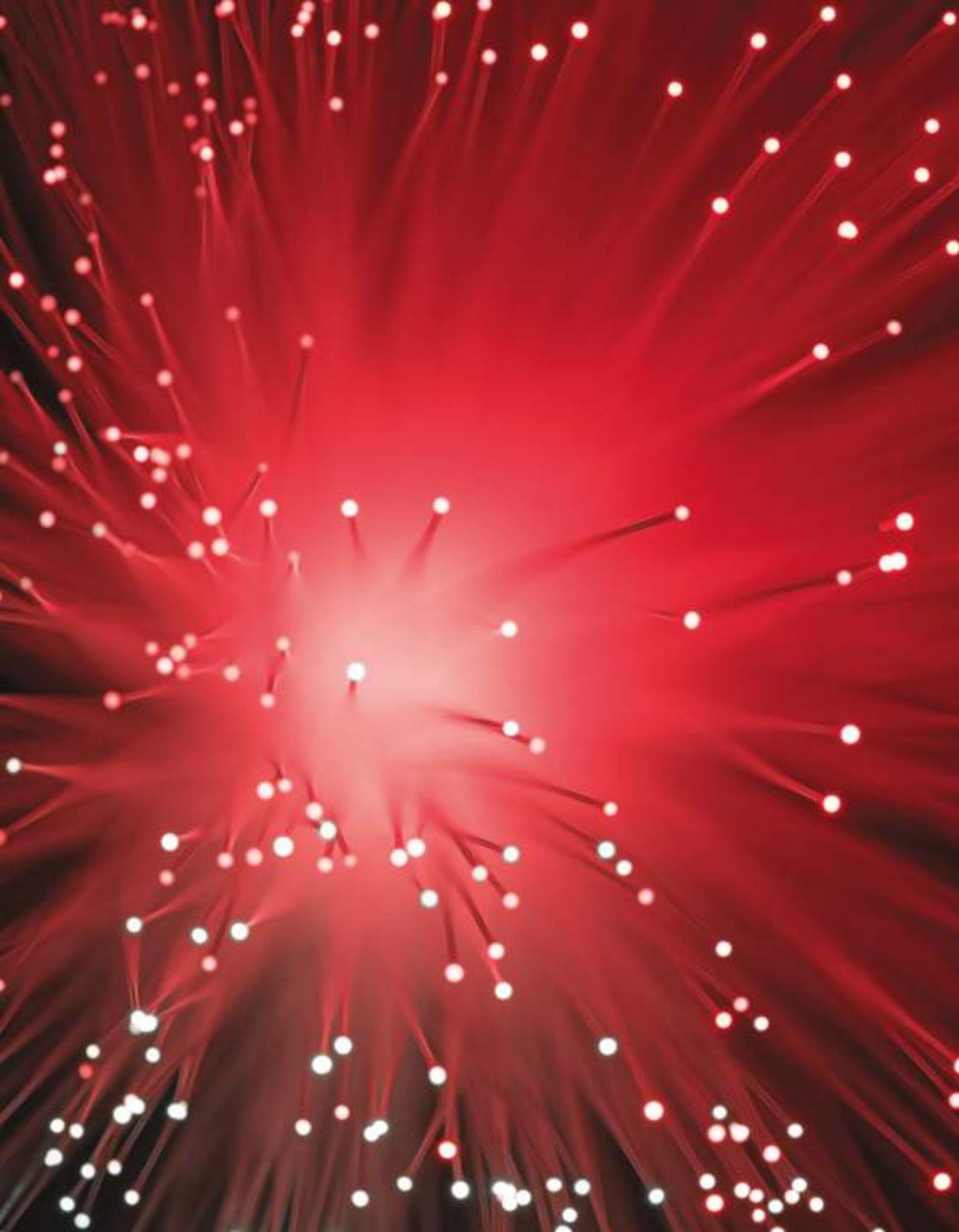
1. Satisfying domestic and foreign companies' demand for highly-skilled human resources in matters of information technology, through strict, and regular certifications to keep knowledge up to date.
2. Opportunely identify future technological enablers, such as cyber security, artificial intelligence, and virtual reality, to foster their development in the country.
3. Enforce respect for intellectual property.
4. Manage innovation by encouraging the implementation of new technologies in the different economic sectors.
5. Maintain a close relationship among the different players of the triple helix to create new business opportunities in the sector.
6. Promote Mexico as an attractive platform for IT investment.

Now, Mexican IT has been known for offering services in a wide, multidisciplinary range of areas that require specialized knowledge management. Some examples of these services are:

- Assessment of technological and digital requirements.
- Information flow analysis.
- Execution of projects requiring technological solutions.
- Determination and assignment of resources to digital transformation projects.
- Design of strategies to implement technological services and platforms.
- Design of applications and systems.
- Reengineering in response to results analysis.

Likewise, Mexico stands out for the close relationship between government, corporations and universities, particularly in the IT sector. This relationship has produced benefits such as joint identification of work opportunities, creation and growth of high technology companies, attention to new market niches, and increase in competitiveness at a local, national or international level. Also, and thanks to the involvements and coordination of IT specialized clusters, the triple helix can engage in several collaborative high-impact projects. Two success stories worth mentioning are the Program for Technological Innovation of High Value-Added Businesses and the Program for the Development of the Software Industry (Prosoft 3.0), which have helped create models and strategies to create innovative companies and foster the country's spin-offs.

As shown and detailed the previous sections, Mexico is global a referent in advanced manufacturing. Proof of this is its participation, as a partner country, in Hannover Messe 2018, one of the major industrial trade fairs, which brings together the world's main players in industrial innovation. Nowadays, Mexico has created a favourable ecosystem to attract investment and develop talent; thus, strengthening the productive capacities necessary to increase the value-added offering and competitiveness of the different Mexican strategic sectors, both internally as externally. Competitiveness clusters are the foundations of this ecosystem.




Automation
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1.2 MEXICAN INDUSTRIAL COMPETITIVENESS AND INNOVATION CLUSTERS

In the digital era, technological innovation entails significant changes in the way goods and services are produced. The current approach to new industrial technologies is focused on generating, gathering, processing, and managing large amounts of data. In manufacturing, this translates into a new productive paradigm: i4.0. Advances, such as the IoT, system integration, process automation through collaborative robots, virtual and augmented reality, cloud computing, and Big Data simulation and analysis software give way to a new type of hyper-flexible manufacturing which can adapt quickly to changes in the market and the different requirements of each process, from design to marketing.

With that in mind, ProMéxico has conducted several studies to identify capabilities, key players, strategic projects, opportunity areas, and new trends in Mexican industries to, then, improve their competitiveness. The current chapter revisits one of these studies which main goal is to geographically identify clusters of those players taking part in and leading the development of i4.0-oriented advanced manufacturing activities in Mexico. The goal is to spot those competitiveness clusters working in industrial innovation in Mexico; there are at least 35 clusters across 16 states, which are then organized in categories based on i4.0 tendencies.

1.2.1 CLUSTER IDENTIFICATION

A competitiveness cluster is a group of triple helix players (government, academia, and private sector) gathered in a common territory and collaborating in innovative projects geared to certain markets. These players come from multinational companies, chambers of commerce, laboratories and research centers to public institutions that support manufacturing.

To identify these competitiveness clusters, we worked around five thematic axes covering key aspects of industrial productive processes with an i4.0 approach. In doing so, we identified and classified clusters according to their players activities:

1. Research, development, and technology.
2. Digital factories.
3. Automation integration, movement, and control.
4. Energy (industrial efficiency and storage).
5. Industrial supply.

There are three eligibility criteria to define a competitiveness cluster:

- It is composed of groups or collectives organized as a cluster, network or association representative of the triple helix where at least one of the players provides the cluster with a certain degree of cohesion and identity by being recognized by the state.
- It is located is a defined geographical area, be it a city, a metropolitan area or a state.
- It offers several different forms of collaboration in line with the needs of its members and their respective markets.

List, classification, and distribution

Naturally, competitiveness clusters can be included in more than one subject classification. To solve this, we set out a specialization for each cluster according to their main activity area. If necessary, we also included one or more subject sub classification based on those other areas covered by the cluster but that are not their main work focus. Likewise, we included three networks that function as a complementary institution to the clusters. Their relevance stems from

the insertion of their technological and innovative capacities in several of the industries covered by the clusters.

The following table lists the names of the competitiveness clusters, together with the state where they are located, their specialization, and their secondary topic areas.

	Alignment with i4.0 Thematic axes				
Name of the cluster	Research, development, and technology	Digital factories	Automation integration, movement, and control	Energy (inudstrial efficiency and storage)	Industrial supply
AGUASCALIENTES					
Innovatia Cluster (Clúster Innovatia)					
Aguacalientes Automotive Cluster (Clúster del Ramo Automotriz de Aguascalientes)					
BAJA CALIFORNIA					
Baja California Electronics Industry Pool (Agrupamiento de la Industria Electrónica de Baja California)					
Baja California Aerospace Cluster (Clúster Aeroespacial de Baja California)					
IT@Baja					
CHIHUAHUA					
Innovation and Technological Transfer Park (Parque de Innovación y Transferencia Tecnológica - PIT2)					
Chihuahua Aerospace Cluster					
Chihuahua Advanced Manufacturing Cluster (Clúster de Manufactura Avanzada de Chihuahua)					
Chihuahua AutoCluster (AutoCluster Chihuahua)					
COAHUILA					
Coahuila Automotive Cluster (La Laguna - Saltillo) (Clúster Automotriz de Coahuila (La Laguna - Saltillo))					
MEXICO CITY					
Mexico City IT Cluster (ProSoftware) (Clúster de Tecnologías de la Información de Ciudad de México (ProSoftware))					
ESTADO DE MÉXICO					
Estado de México Automotive Cluster (Clúster Automotriz del Estado de México)					
GUANAJUATO					
Guanajuato Automotive Cluster (Clúster Automotriz de Guanajuato)					
HIDALGO					
Scientific and Technological Park of the Autonomous University of the State of Hidalgo (Parque Científico y Tecnológico de la Universidad Autónoma del Estado de Hidalgo)					

Name of the cluster	Alignment with i4.0 Thematic axes				
	Research, development, and technology	Digital factories	Automation integration, movement, and control	Energy (inudstrial efficiency and storage)	Industrial supply
JALISCO					
Jalisco IT Hub (Polo de Tecnologías de la Información de Jalisco)					
Jalisco Electronics Industry Pool (Agrupamiento de la Industria Electrónica de Jalisco)					
State of Jalisco Advanced Manufacturing and i4.0 Initiative (Iniciativa de Manufactura avanzada e Industria 4.0 del Estado de Jalisco)					
MICHOACÁN					
Querétaro Technological Park (Parque Tecnológico Querétaro)					
NUEVO LEÓN					
Research & Technological Innovation Park - PIIT (Parque de Investigación e Innovación Tecnológica (PIIT))					
Nuevo León Automotive Cluster (Clúster Automotriz de Nuevo León)					
Nuevo León Nanotechnology Cluster (Clúster de Nanotecnología de Nuevo León)					
CSoftMty - ICT Cluster (CSoftMty (Clúster TICS))					
Nuevo León State i4.0 Strategy (Estrategia Estatal de Industria 4.0 - Nuevo León)					
Aerocluster Monterrey					
PUEBLA					
Puebla CIT Technological Park (Parque Tecnológico CIT de Puebla)					
Central Region Automotive Cluster (Clúster Automotriz de la Zona Centro)					
Puebla IT Innovation Cluster (Clúster para la Innovación en Tecnologías de la Información de Puebla)					
QUERÉTARO					
ITESM Querétaro Technological Park (Parque Tecnológico ITESM Querétaro)					
InteQSoft Cluster					
Aerocluster Querétaro					
Querétaro Technology, Engineering, and Design Centers Hub (Polo de Centros Tecnológicos, de Ingeniería y Diseño de Querétaro)					
Innovation and Creativity 4.0 Center - Technological University of Querétaro (Centro de Innovación y Creatividad 4.0 - Universidad Tecnológica de Querétaro)					

Name of the cluster	Alignment with i4.0 Thematic axes				
	Research, development, and technology	Digital factories	Automation integration, movement, and control	Energy (inudstrial efficiency and storage)	Industrial supply
SAN LUIS POTOSÍ					
San Luis Potosí Automotive Cluster (Clúster Automotriz de San Luis Potosí)					
SONORA					
Sonora Aerospace Initiative Cluster (Iniciativa Clúster Aeroespacial de Sonora)					
TAMAULIPAS					
Tamaulipas Scientific and Technological Park - TECNOTAM (Parque Científico y Tecnológico de Tamaulipas (TECNOTAM))					
NETWORK					
Complex Systems Conacyt Network (Red Conacyt Sistemas Complejos)					
Automotive Industry Technological Support Centers Strategy - Estrategia de Centros para la Atención Tecnológica de la Industria (ECATI) Automotriz					
Nanoscience and Nanotechnology Thematic Network (Red Temática de Nanociencias y Nanotecnología)					

Specialization	
Secondary topic area	
No activity on the subject	

As shown in the table above, Mexico has 35 competitiveness clusters in 16 federal entities, plus 3 collaboration networks. Below is their distribution according to their alignment with the five thematic axes:

Topic area	Number of clusters specialized in the topic area	Number of clusters covering it as a secondary topic area	Total number of clusters addressing the topic area
Research, development, and technology	9	21	30 (+3 networks)
Digital factories	9	20	29
Automation integration, movement, and control	2	26	28
Industrial supply	15	10	25
Energy (industrial efficiency and storage)	0	7	7
TOTAL	35		

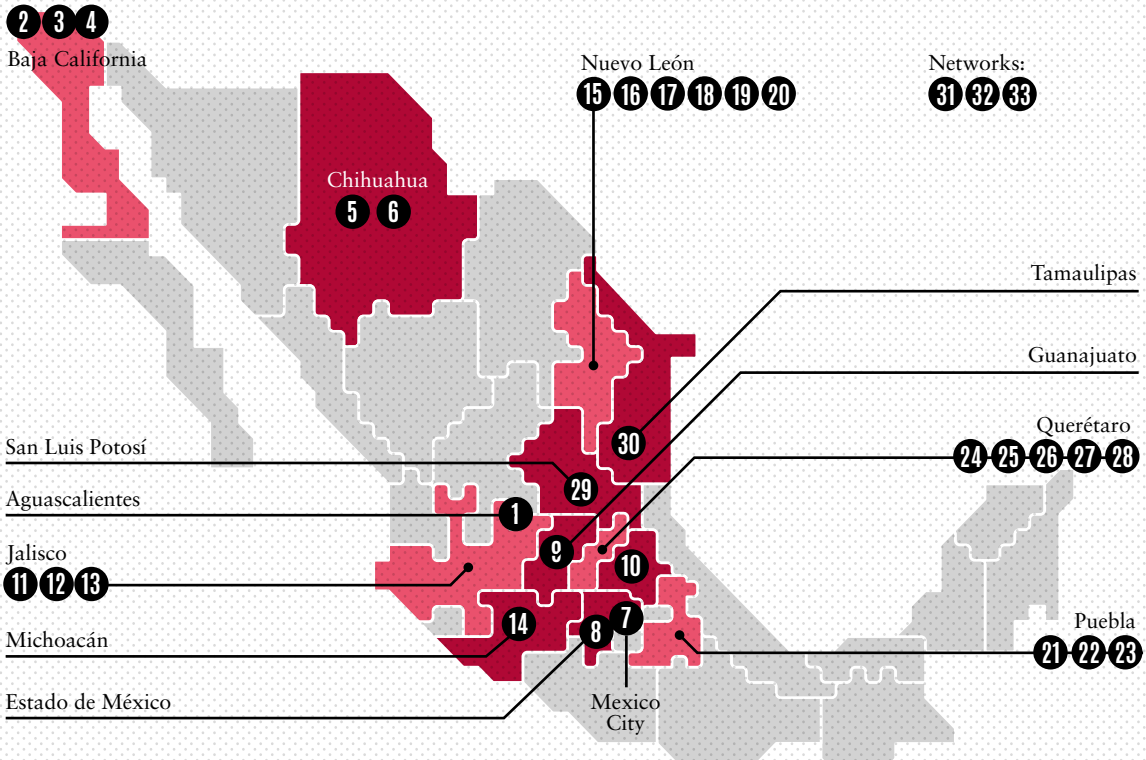
1.2.2 COMPETITIVENESS CLUSTERS MAPPING

The following section includes five maps, each displaying the location of industrial innovation competitiveness clusters by thematic axis, stating whether it is their specialism or their secondary topic area.

RESEARCH, DEVELOPMENT AND TECHNOLOGY

1. Clúster del Ramo Automotriz de Aguascalientes
2. Agrupamiento de la Industria Electrónica de Baja California
3. IT@Baja
4. Clúster Aeroespacial de Baja California
5. Parque de Innovación y Transferencia Tecnológica (PIT2)
6. Chihuahua Aerospace Cluster
7. Clúster de Tecnologías de la Información de Ciudad de México (ProSoftware)
8. Clúster Automotriz del Estado de México
9. Clúster Automotriz de Guanajuato
10. Parque Científico y Tecnológico de la UAEH*
11. Polo de Tecnologías de la Información de Jalisco
12. Agrupamiento de la Industria Electrónica de Jalisco
13. Iniciativa de Manufactura Avanzada/ Industria 4.0 del Estado de Jalisco
14. Clustertim Parque Tecnológico
15. Parque de Investigación e Innovación Tecnológica (PIIT)
16. Clúster Automotriz de Nuevo León
17. Clúster de Nanotecnología de Nuevo León
18. CSoftMty (ITC cluster)
19. Aerocluster Monterrey
20. Estrategia estatal de industria 4.0 - Nuevo León
21. Parque Tecnológico CIT de Puebla
22. Clúster Automotriz de la Zona Centro
23. Clúster para la Innovación en TI de Puebla
24. Parque Tecnológico ITESM Querétaro
25. Clúster IteQSoft
26. Aerocluster Querétaro
27. Polo de Centros Tecnológicos de Ingeniería y Diseño de Querétaro
28. Centro de Innovación y Creatividad 4.0+
29. Clúster Automotriz de San Luis Potosí
30. Parque Científico y Tecnológico de Tamaulipas (TECNOTAM)
31. Red Conacyt Sistemas Complejos
32. Red ECATI Automotriz
33. Red Temática de Nanociencias y Nanotecnología

The states in lighter color have three or more clusters. Those clusters specialized in the topic area are highlighted in the list.



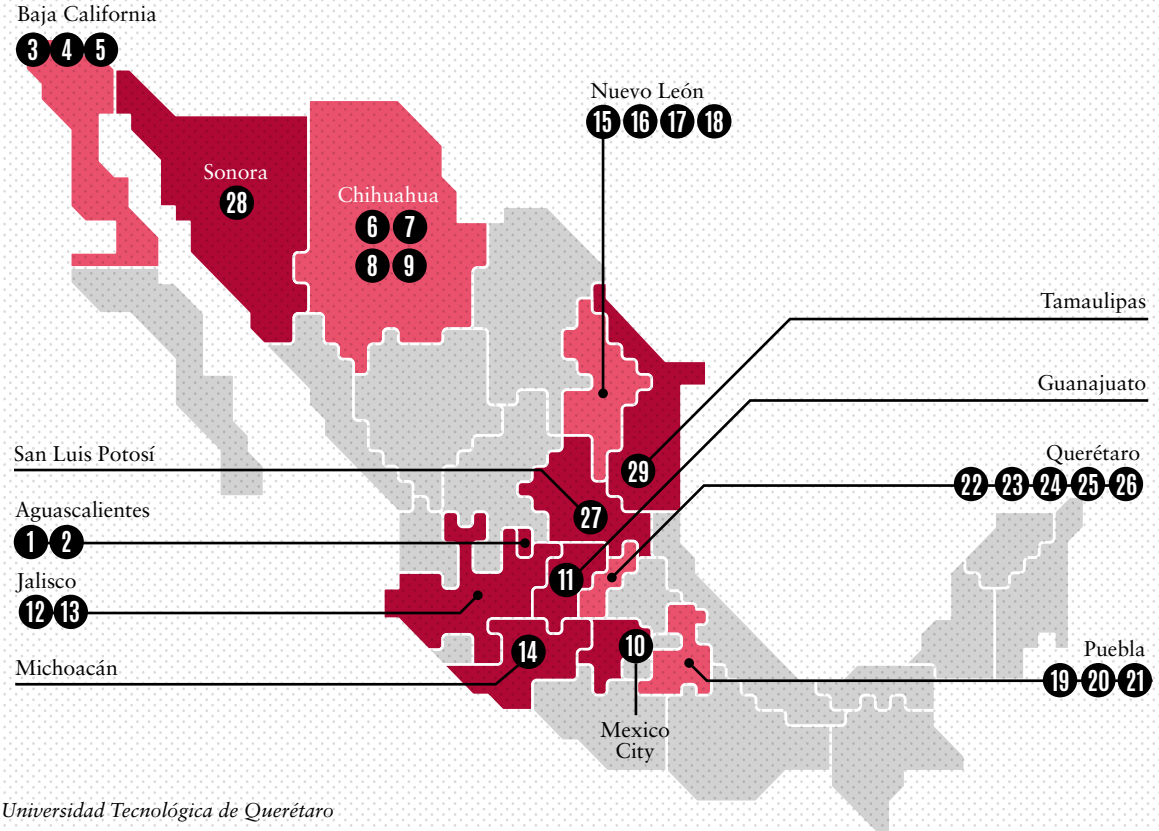
*Universidad Autónoma del Estado de Hidalgo

+Universidad Tecnológica de Querétaro

DIGITAL FACTORIES

1. Clúster Innovatia
2. Clúster del Ramo Automotriz de Aguascalientes
3. Agrupamiento de la Industria Electrónica de Baja California
4. Clúster Aeroespacial de Baja California
5. IT@Baja
6. Chihuahua Aerospace Clúster
7. Clúster de Manufactura Avanzada de Chihuahua
8. AutoCluster Chihuahua
9. Parque de Innovación y Transferencia Tecnológica (PIT2)
10. Clúster de Tecnologías de la Información de Ciudad de México (ProSoftware)
11. Clúster Automotriz de Guanajuato
12. Polo de TI de Jalisco
13. Agrupamiento de la Industria Electrónica de Jalisco
14. Clusterim Parque Tecnológico
15. Parque de Investigación e Innovación Tecnológica de Nuevo León (PIIT)
16. Clúster Automotriz de Nuevo León
17. CSoftMty (ITC Cluster)
18. Estrategia Estatal de la Industria 4.0 Nuevo León
19. Parque Tecnológico CIT de Puebla
20. Clúster Automotriz de la Zona Centro
21. Clúster para la Innovación en TI de Puebla
22. Parque Tecnológico ITESM Querétaro
23. Clúster IteQSoft
24. Aerocluster Querétaro
25. Polo de Centros Tecnológicos de Ingeniería y Diseño de Querétaro
26. Centro de Innovación y Creatividad*
27. Clúster Automotriz de San Luis Potosí
28. Iniciativa Clúster Aeroespacial de Sonora
29. Parque Científico y Tecnológico de Tamaulipas (TECNOTAM)

The states in lighter color have three or more clusters. Those clusters specialized in the topic area are highlighted in the list.

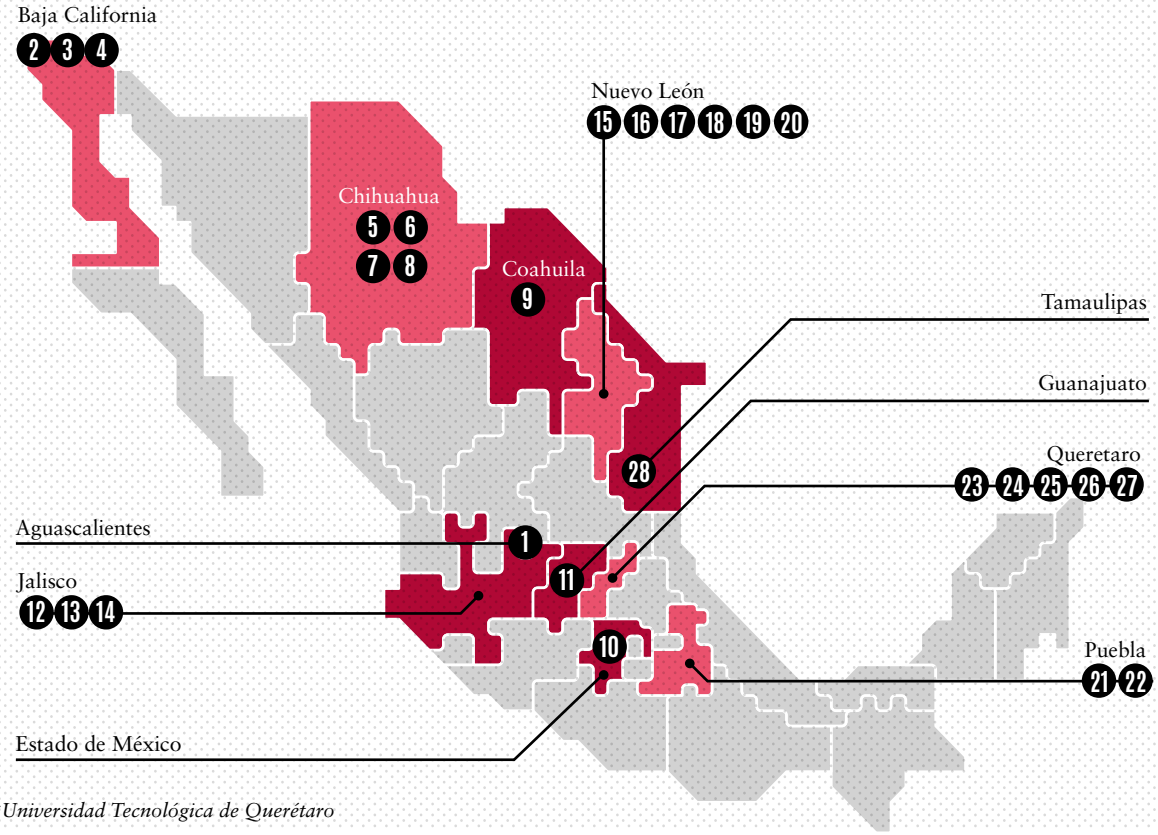


**Universidad Tecnológica de Querétaro*

AUTOMATION INTEGRATION, MOVEMENT AND CONTROL

1. Clúster del Ramo Automotriz de Aguascalientes
2. Agrupamiento de la Industria Electrónica de baja California
3. Clúster Aeroespacial de Baja California
4. IT@Baja
5. Parque de Innovación y Transferencia Tecnológica(PIT2)
6. Chihuahua Aerospace Clúster
7. Clúster de Manufactura Avanzada de Chihuahua
8. AutoCluster Chihuahua
9. Clúster Automotriz de Coahuila (La Laguna-Saltillo)
10. Clúster Automotriz del Estado de México
11. Clúster Automotriz de Guanajuato
12. Polo de TI de Jalisco
13. Agrupamiento de la Industria Electrónica de Jalisco
14. Iniciativa de Manufactura Avanzada e Industria 4.0 del Estado de Jalisco
15. Parque de Investigación e Innovación Tecnológica (PIIT)
16. Clúster Automotriz de Nuevo León
17. Clúster de Nanotecnología de Nuevo León
18. CSoftMty (ITC Cluster)
19. Estrategia Estatal de la Industria 4.0 Nuevo León
20. Aerocluster Monterrey
21. Parque Tecnológico CIT de Puebla
22. Clúster Automotriz de la Zona Centro
23. Parque Tecnológico ITESM Querétaro
24. Clúster IteQSoft
25. Aerocluster Querétaro
26. Polo de Centros Tecnológicos de Ingeniería y Diseño de Querétaro
27. Centro de Innovación y Creatividad 4.0*
28. Parque Científico y Tecnológico de Tamaulipas (TECNOTAM)

The states in lighter color have three or more clusters. Those clusters specialized in the topic area are highlighted in the list.

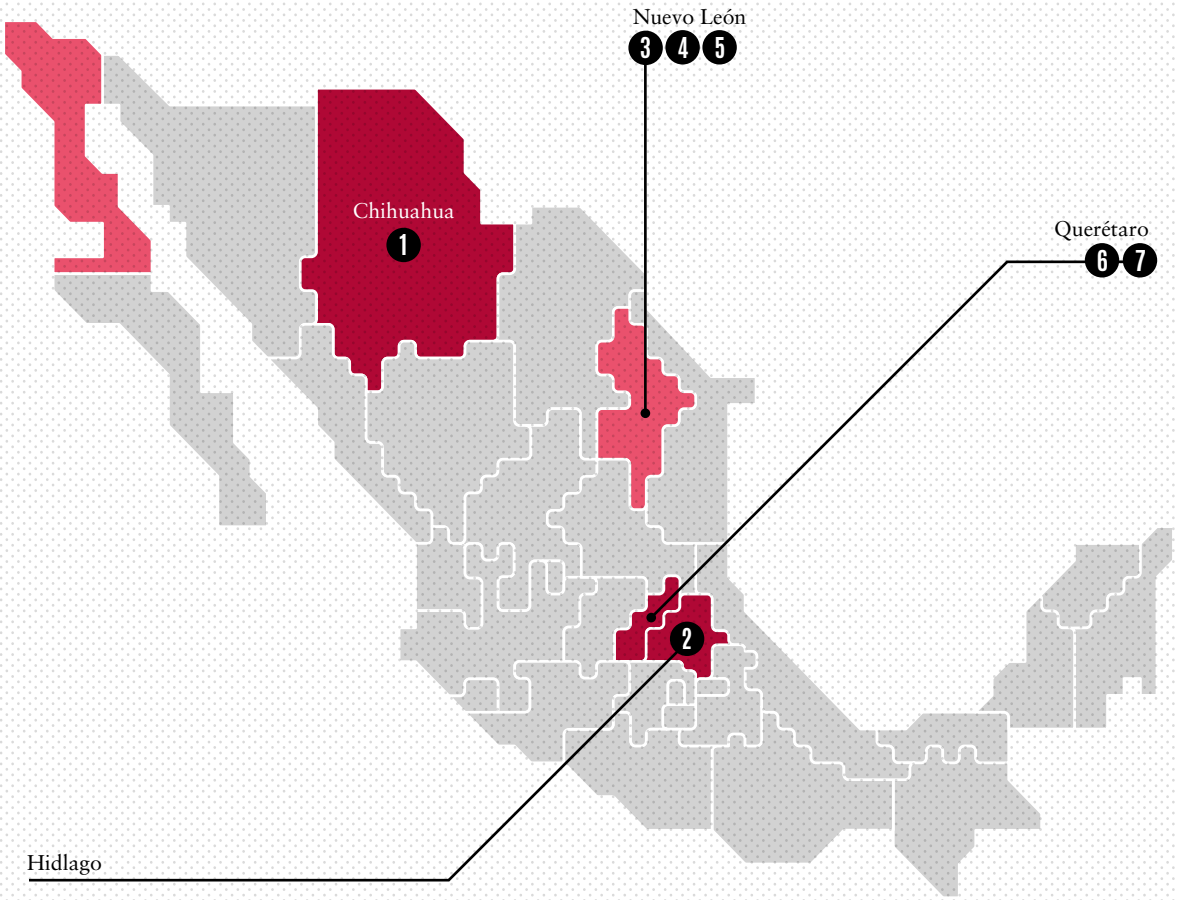


*Universidad Tecnológica de Querétaro

ENERGY (INDUSTRIAL EFFICIENCY AND STORAGE)

1. Parque de Innovación y Transferencia Tecnológica (PIT2) de Coahuila
2. Parque Científico y Tecnológico de la Universidad Autónoma del Estado de Hidalgo
3. Parque de Investigación e Innovación Tecnológica (PIIT) de Nuevo León
4. Estrategia Estatal de Industria 4.0 - Nuevo León
5. Clúster de Nanotecnología de Nuevo León
6. Polo de Centros Tecnológicos de Ingeniería y Diseño de Querétaro
7. Centro de Innovación y Creatividad 4.0 (Universidad Tecnológica de Querétaro)

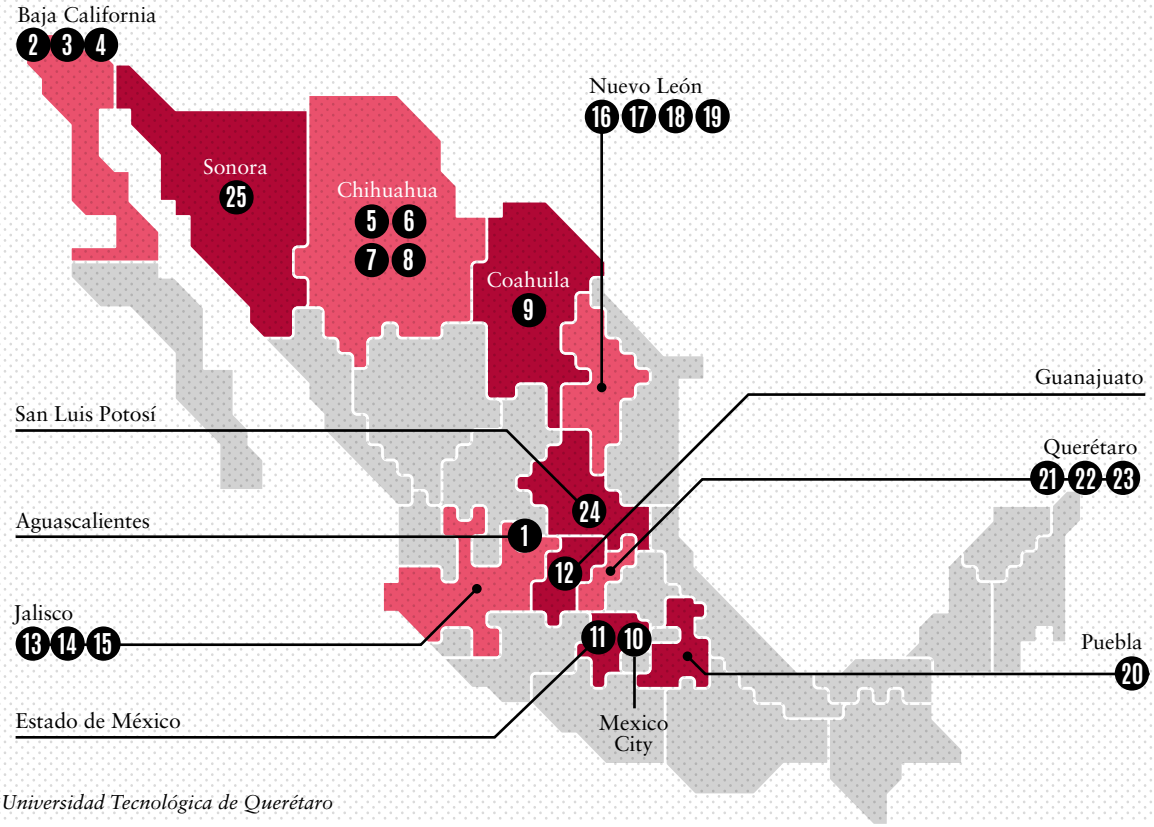
The states in lighter color have three or more clusters. None of these poles has this topic as main concentration.



INDUSTRIAL SUPPLY

1. Clúster del Ramo Automotriz de Aguascalientes
2. Agrupamiento de la Industria Electrónica de Baja California
3. Clúster Aeroespacial de Baja California
4. IT@Baja
5. Parque de Innovación y Transferencia Tecnológica (PIT2)
6. Chihuahua Aerospace Clúster
7. Clúster de Manufactura Avanzada de Chihuahua
8. AutoCluster Chihuahua
9. Clúster Automotriz de Coahuila (La Laguna-Saltillo)
10. Clúster de Tecnologías de la Información de Ciudad de México (ProSoftware)
11. Clúster Automotriz del Estado de México
12. Clúster Automotriz de Guanajuato
13. Polo de TI de Jalisco
14. Agrupamiento de la Industria Electrónica de Jalisco
15. Iniciativa de Manufactura Avanzada e Industria 4.0 del Estado de Jalisco
16. Parque de Investigación e Innovación Tecnológica (PIIT) de Nuevo León
17. Clúster Automotriz de Nuevo León
18. Aerocluster Monterrey
19. Estrategia Estatal de Industria 4.0 - Nuevo León
20. Clúster Automotriz de la Zona Centro (Puebla - Tlaxcala)
21. Aerocluster Querétaro
22. Polo de Centros Tecnológicos de Ingeniería y Diseño de Querétaro
23. Centro de Innovación y Creatividad 4.0*
24. Clúster Automotriz de San Luis Potosí
25. Iniciativa Clúster Aeroespacial de Sonora

The states in lighter color have three or more clusters. Those clusters specialized in the topic area are highlighted in the list.



Universidad Tecnológica de Querétaro

1.2.3 KEY TRENDS AMONG MEXICO'S COMPETITIVENESS CLUSTERS

As shown in the last map, the primary focus of Mexican competitiveness clusters is industrial supply, with 15 clusters. This falls in line with the logic behind the idea of a 'competitiveness cluster', as their very existence is based on producing and marketing products that satisfy the needs of diverse markets. In fact, competitiveness clusters specialized in this topic area gather large multinational companies and SMEs from the aerospace and automotive industries; two Mexican sectors that satisfy foreign demand. It is worth mentioning that there are many SMEs in the country, which serve as supplier base for large investments and that are expected to develop greater collaborative synergies that, in turn, help to create more clusters specialized in industrial supplies.

The second most recurrent thematic axis is research, development, and technology with nine specialized competitiveness clusters established around research centers, and both public and private universities. However, if we count those that hold research, development, innovation, and science and technology transfers as their secondary topic area, then the total amounts to 30 competitiveness clusters; thus, becoming the most recurrent thematic axis. Although federal and state policies only recently started promoting R&D&i, the fact that, in absolute terms, most of the clusters work on these topic areas is a sign that Mexico is not only a manufacturing center but also offers a favorable climate for research and design. Likewise, there are nine competitiveness clusters specialized in digital factories, where ICT plays a prominent role that is closely linked to the IoT, an essential requirement for establishing intelligent factories.

We have only identified two competitiveness clusters specialized in the thematic axis Automation integration, movement, and control. One of them focuses on the automotive industry and the other one on IT, but both develop projects aimed at bolstering manufacturing processes automation. Finally, it is worth mentioning that none of the competitiveness clusters specializes in energy efficiency and storage. This could be due to the fact that in Mexico, energy issues usually revolve around hydrocarbons and renewable electricity production. There are clusters, especially those that operate in a park-like manner, that utilize wind and solar energy to satisfy their own energy needs. There are still plenty of opportunities for development and implementation of industrial energy efficiency and storage technologies.

Geographically, most clusters locate in the northern, central, and norther-central regions of the country; which coincides with the historical manufacturing specialization of this regions, now focused on exports production. The three states with the most competitiveness clusters, classified only by their primary topic area, are Nuevo León —six clusters—, Querétaro —five clusters—, and Chihuahua —four clusters. By contrast, as this economic activity is not predominant in the south-eastern region of the country, there are no clusters working in any of the thematic axes analyzed.

According to their organizational modalities, there are industry clusters in 21 of the competitiveness clusters; that is groups of similar and related firms in a defined geographic area. In fact, given that we are looking for articulated agglomerations with a common identity, proximity, recognition, and projects, it is only natural for the notion of 'industry clusters' to conceptually overlap with that of 'competitiveness clusters; thus, making them harder to identify. In addition, fostering competitiveness through cluster development has been encouraged by government policies throughout this century. Unlike industry clusters, competitiveness clusters necessarily work under a triple helix approach (including government agencies, businesses, chambers of commerce, universities, and research centers), so much so that, without government or academia participation, an industry cluster would not be considered as a competitiveness cluster. Another organizational modality falls under the category of 'initiatives'; such is the case of noteworthy collaborative synergies that have not yet been established under a formal articulation body and representation. We have identified eight of such cases. A third and final modality entails the existence of a physical space, commonly referred to as technological or scientific 'park', where the competitiveness clusters' members conglomerate. We have identified six such cases.

Sector wise, there is a strong presence of the following: IT (15 competitiveness clusters), automotive (11 competitiveness clusters), metal-mechanic (10 competitiveness clusters), and aerospace (8 competitiveness clusters). These sectors have been recognized by the governments of the states of

Baja California, Nuevo León, Aguascalientes, Querétaro, and Jalisco as strategic sectors given their economic importance and their scientific-technological potential. Thus, governments have actively encouraged their development through different public policies fostering R&D&i, technology transfer, specialized training, and foreign investment. In doing so, these competitiveness clusters have been at the forefront of cutting-edge technology implementation.

It is worth mentioning that the metal-mechanic industry goes hand in hand with the automotive and aerospace sectors, as they relay on forging and assembly. Other sectors found are: electronics (4 competitiveness clusters), nanotechnology (3 competitiveness clusters), advanced materials (3 competitiveness clusters), medical devices (3 competitiveness clusters), energy (2 competitiveness clusters), biotechnology (2 competitiveness clusters), and telecommunications (2 competitiveness clusters). A common denominator in terms of collaboration, regardless of the industry, is the existence of educational and training programs by both the academia and private sector, support schemes to establish competitive Tier 1 and Tier 2 supply companies.

Another finding worth mentioning, but that requires further validation, is the fact that industrial innovation clusters are a fairly recent phenomenon in Mexico. Approximately 71% of the 35 competitiveness clusters analyzed here only began to operate during the last decade; that is, between 2007 and 2017. This is even more evident considering that 90% of them came into existence during the 21st century. In fact, only three competitiveness clusters predate the turn of the century, all three of them count the presence of the electronics industry, as it was one of the first industries to be boosted by the North American Free Trade Agreement.

Another interesting finding is that these competitiveness clusters are important sources of employment. On average, each one of them groups 116 companies employing around 26,000 people. Even though some of these companies belong to labor intensive sectors, such as the maquila industries in Baja California and Chihuahua or the large automotive assembly plants in Guanajuato and San Luis Potosí, most of the companies are SMEs. In terms of job quality, it would be fair to say that given the types of activities specialized in R&D, engineering, software development, among other factors, most of the jobs are qualified jobs; however, job quality was not within the scope of the present study and we will have to study it later.

Although most of the competitiveness clusters are still at an initial stage formulating plans, articulating efforts, and generating new capacities, it is worth mentioning that there are more mature competitiveness clusters with clear strengths by virtue of the sum of their corporate, governmental, and academic members' economic and human resources. Below, we describe some of the most noteworthy cases:

Noteworthy Competitiveness Clusters	
Baja California Electronics Industry Cluster (Agrupamiento de la Industria Electrónica de Baja California)	A mature pool with decades of experience creating and developing capacities that counts among its members international companies from Japan, South Korea, China, the United States, and Europe and that has helped to launch and monitor projects together with the maquila industry, chambers of commerce, universities, and the three levels of government. Currently, it is working towards increasing its level of specialisation under the impetus of the National Electronics, Telecommunications, and IT Chamber (CANIETI) and the Ministry of Economy by incorporating advanced manufacturing and R&D to its activities, in order to foster growth in the sector's main segment in Baja California.

Noteworthy Competitiveness Clusters	
Innovation and Technological Transfer Park (Parque de Innovación y Transferencia Tecnológica - PITT2)	Under the leadership of the local business community and the Technological Institute of Monterrey, the Chihuahua campus is outgrowing its current park status and slowly becoming a proper ecosystem for innovation. The competitiveness cluster actively fosters technological development, business incubation, and human talent training. In addition, they benefit from venture capital and market access to boost the growth of existing companies in the region or the establishment of new ones.
Guanajuato Automotive Industry Cluster (Clúster Automotriz de Guanajuato)	Having the automotive industry only started to grow exponentially during the last decade through investment by 'anchor' companies, such as Volkswagen, Pirelli, Mazda, and General Motors (the latter earlier than the formers) and by a series of inputs and auto parts suppliers and service providers, Guanajuato has put together a further specialisation strategy. Together with the state government, the cluster has fostered training schemes and is promoting the creation of a new technological center to facilitate research and development. Currently, the Center for Applied Innovation in Competitive Technologies satisfies the sector's technological needs and, being part of the ECATI Automotive Network, it is well-positioned to broaden the scope of technological services offered to automotive and auto parts companies.
Jalisco IT Competitiveness Cluster (Polo de Tecnologías de la Información de Jalisco)	Having bet hard on developing the software industry since the turn of the century and having consistently invested in capacity building (training, equipment, and certification), Jalisco is ripe to expand its trade base and consolidate its infrastructure. Thus, it is known for its high competitiveness. The support by federal programs, such as Prosoft, and the state government through the State Council for Science and Technology and, more recently, the Ministry of Innovation, Science, and Technology, are helping to expand the outreach of IT and other activities and sectors. Nowadays, the members of this competitiveness cluster are among the most relevant Mexican players in applying digital technologies to manufacturing.
Jalisco Electronics Industry Cluster (Agrupamiento de la Industria Electrónica de Jalisco)	Often dubbed the 'Mexican Silicon Valley', this cluster has been fostered by the National Electronics, Telecommunications, and IT Chamber (CANIETI). In order to enhance specialization in productive chains articulation, CANIETI created the Electronic Productive Chain program, which has successfully helped to develop regional suppliers. Initially, American technological companies, such as HP and IBM, laid the foundations for the creation of this cluster. Later, with the arrival of contract manufacturing companies, new supply dynamics came into being and contributed to the development and specialisation of innovation and technology development capacities. The companies and CANIETI have promoted links with local higher education entities, such as the Technological and Higher Studies Institute of Monterrey, the Western Technological and Higher Studies Institute, and the Autonomous University of Guadalajara, just to mention a few.

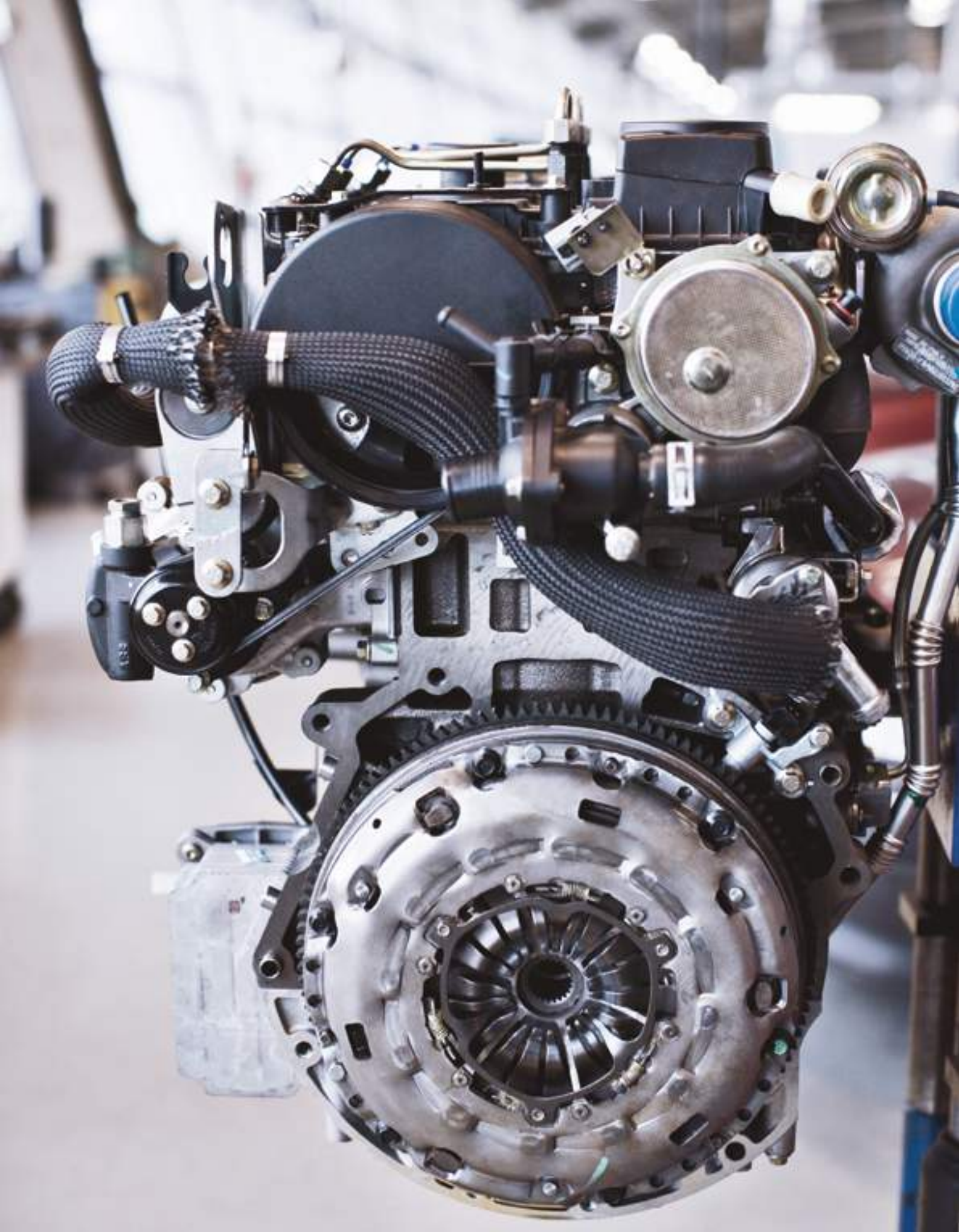
Noteworthy Competitiveness Clusters	
Research & Technological Innovation Park - PIIT (Parque de Investigación e Innovación Tecnológica (PIIT))	This might possibly be the best example of a competitiveness cluster born out of a brand new physical space that aggregated players around innovation. Fostered by the government of Nuevo León, this park houses two types of research and development centers, public and private, and continues to grow in terms of guests. It is also worth mentioning the significant public infrastructure policy that has helped to develop the cluster and consolidate its capacities in a very short period of time. The PIIT has managed to align the capacities of the centers it hots with its own goals geared towards advanced manufacturing and advanced materials development. This is one of the competitiveness clusters where activities and projects related to all five i4.0 thematic axes are conducted.
Nuevo León Nanotechnology Industry Cluster (Clúster de Nanotecnología de Nuevo León)	Being nanotechnology a new and growing field in Mexico, it is difficult to find other clusters bringing together many public and private players working in the area. This cluster concentrates most of the area's national scientific and technological capacities. Despite still being at the early development stages, it comprises several companies developing advanced materials and an incubator equipped with basic and advanced equipment to support new projects during their initial and testing states.
InteQSoft Cluster	This IT cluster, located in Querétaro, has been a positive and important articulator of inter-institutional efforts to promote specialisation of its member companies in new i4.0 and IoT technologies. Not only does the competitiveness cluster has a clear leadership and strategy, but it is also highly efficient in integrating academic and governmental efforts in numerous collaborative projects.
Aerocluster Querétaro	Unlike other aerospace clusters, Querétaro's triple helix has boosted productive chain integration links with academia to train highly-skilled personnel, and has created a geographical cluster that aggregates important players around the city's international airport. Querétaro has a high concentration of research centers, which have also sought to articulate with the aerospace sector, especially the Querétaro Technology, Engineering, and Design Center (CIATEQ) and the Electrochemical Technological Research and Development Center (CIDETEQ).

1.2.4 THEMATIC NETWORKS

Besides the competitiveness clusters, there are different thematic networks in Mexico bringing together players interested in joining capacities to facilitate technological and innovative insertion in vertical industries, such as automotive and aerospace, and in less vertical ones, such IT and nanotechnology. There are three thematic networks working primarily around i4.0 technological research and development, each with their highly-specialized research axes linked to their own sectors. They come together in research centers, laboratories, and public and private universities, some within the clusters' sphere of influence. The neteworks are formally supported by Conacyt during the last decade with the goal of maximizing the installed capacity of its members through communication networks and close collaboration, seeking to strengthen their capacities with a market approach.

On the other hand, these networks also came into existence in response to the complexities of the normative framework that makes it difficult to create new public centers due to budgetary constraints. In order to enhance their resource management and to generate higher impact projects, these satellite or sub-center networks were created around already existing organizations so that they could collaborate with private companies in ways similar to those of the competitiveness clusters. Thus, these networks complement the work of the competitiveness clusters as they coexist within their own scheme and, in addition, become an important link between clusters.

Noteworthy networks	
Automotive Industry Technological Support Centers Strategy - ECATI (Estrategia de Centros para la Atención Tecnológica de la Industria (ECATI) Automotriz)	This was the first vertical network created by Conacyt. Founded in 2016 by 13 public research institutions, it seeks to articulate and aggregate scientific and technological research and development capacities to have direct impact on Mexico's automotive sector. ECATI Automotive has led to the creation of highly specialized centers and laboratories, such as the Aguascalientes Innovation and Technological Transfer Center (CITTAA), based on the Aguascalientes Automotive Cluster and the National Light Materials Innovation and Development Laboratory for the Automotive Industry (Laniauto), and, primarily, the Applied Chemical Research Center (CIQA) in Coahuila's Automotive Cluster (La Laguna - Saltillo).
Nanoscience and Nanotechnology Thematic Network (Red Temática de Nanociencias y Nanotecnología)	One of the largest and best structured thematic networks in the country. It has 480 members working on advanced materials research, among others. In addition, the network actively looks for advocacy opportunities about the many aspects of manufacturing. Supported by Conacyt, this network has its own strategy and promotes the development of technological management capacities among its members, located in more than 60 institutions across the country.



1.3 FINAL REMARKS

The new i4.0 productive paradigm has had, in a short period of time, considerable impact on several Mexican players and sectors. The competitiveness clusters are proof of the country's developing ecosystem, which is robust in manufacturing, design, and implementation of innovative technologies.

Sectors such as aerospace, automotive, electronics, metal-mechanic, medical devices and IT as leading the implementation of i4.0 technologies. Their strategic value stems from foreign investment; however, their growth and development are the result of collaborative synergies among the different triple helix players and the Mexican talent aggregated in the competitiveness clusters.

It is important to highlight the dynamism of these clusters as they create and coordinate collaboration efforts, a task usually in hands of the private initiative willing to generate new business. Mapping Mexico's competitiveness clusters according to i4.0 trends, should help investors to identify where the different players, sectors, and projects are, together with other key elements beneficial to any investment project.

The thematic networks, led by research centers, are also open to develop new business, especially since they have a more practical approach towards the use of their research and design capacities. Likewise, the existence of more than one thematic network within each cluster facilitates project development and implementation by making better use of avaliable resources. Thus, these networks open the door to a new inter competitiveness cluster collaboration dimension.

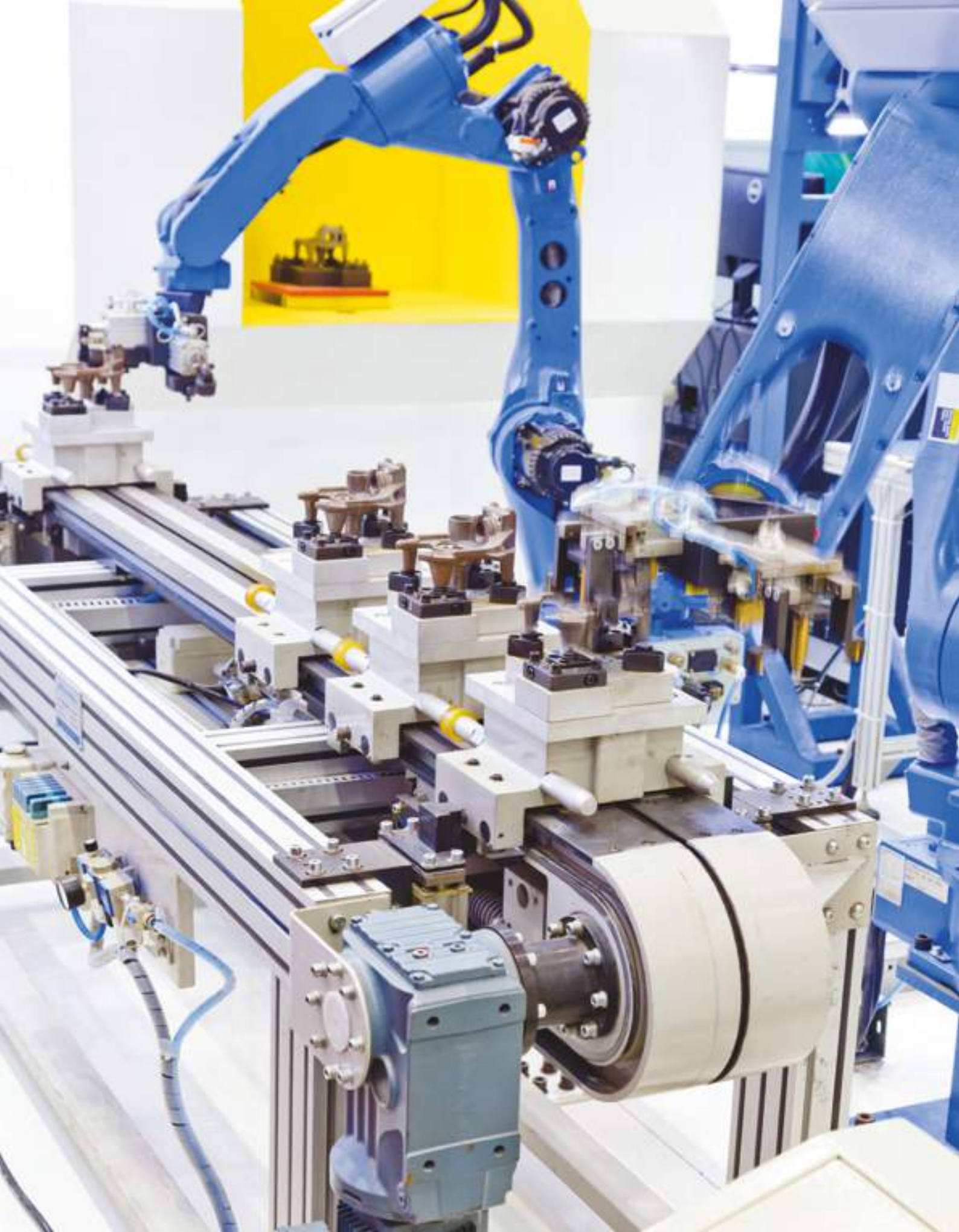
Mexico still faces important challenges which investment can help turn into strengths. Even if Mexican talent implements new technologies successfully, we still need to explore its capacity to develop new technologies, innovate processes, and execute innovation-centered business projects by providing them with funding and guidance. On the other hand, there are opportunities in emerging niche markets for fresh investment and players to develop, supply, and implement technologies related to energy efficiency, automation integration, actioning, and control. Also, international cooperation between businesses and academia, as a means to assimilate knowledge and capacities, is a fertile ground for growth by fostering alliances and bilateral scientific and technological cooperation agreements between research centers, businesses, and governments.

Finally, it is worth repeating that, although we live in an age of rapid technological advances and significant political and economic changes around the world, Mexico has solid strengths ready to boost innovation. In Part Two: *A Platform for Innovation*, Mexico's long-term industrial plans will be explored to provide greater certainty about Mexico's readiness to be a key ally of the world's leaders in industrial innovation —today and always.

PART 2

A PLATFORM FOR INNOVATION

By J. Santiago Rodríguez Suárez



2.1 GLOBAL TRENDS IN INDUSTRIAL INNOVATION

The speed at which technological changes progress reflect the convergence of several development trends: artificial intelligence (AI), IoT, virtual reality, and many other areas that, together, will bring about major changes. In this volume, we analyze five global innovation trends in different sectors that will allow for a better business strategy definition. These trends were chosen for their horizontal alignment with different productive sectors and the synergy that may result from them.

The following chart summarizes the trends analyzed here and shows some of the main technologies, processes or systems leading the transition towards the new productive system, as well as the main countries that are applying them.

TREND	TECHNOLOGY / PROCESS INDUSTRIAL SYSTEM TO WHICH IT IS BEING APPLIED	LEADING COUNTRIES
IoT	Sensors, wiring, networks, AI, advanced analysis and remote monitoring technologies.	Germany, China, the United States, and Singapore
Intelligent Automation	Robots, cobots and advanced control	United States and Japan
Digitalization	Drive systems, engines, pneumatic systems, supply chain, energy generation, transmission, and distribution (virtual power stations, buildings' automation systems), APS, cognitive robots, digital twins, AI, autonomous robots, real-time equipment monitoring.	Germany, United States, and Japan.
3D Printing	Technologies (MDF, SLS, SLA, FSL) and materials such as plastics, resins, and metals.	Germany and United States
Energy Efficiency	Distributed generation, distribution and efficient storage, smart grids and micro-grids, stationary fuel cells and batteries, renewable energy generation (solar, photovoltaic, thermoelectric, wind, biomass).	Germany and United States

Source: ProMéxico.

Our aim is to show that, thanks to its important industrial production and strategic position in global value chains, Mexico is an innovation platform and has the capacity to become an ally for leaders in industrial innovation. Thus, we wish to make known Mexico's particularities as a manufacturing, exporting nation; together with its strengths, its national strategy for disruptive technologies, and the mature sectors that allow the country to implement the different industry 4.0 (i4.0) innovations.

With this in mind, ProMéxico is conducting several studies to provide information that will help determine the strategies to follow in order to profit from the opportunities presented by the development of new technologies for the industries of tomorrow. After having analyzed the adoption of industrial innovation technologies in Mexico, we have identified opportunities for collaboration with leading countries in two strategic areas: strengthening the production chain and developing labor and technological capacities.

It is also worth mentioning some of the public policy recommendations made and aimed at helping to foster these updated strategies in high-impact projects for Mexico's industrial ecosystem; and to narrow the gap with the countries leading the development of innovative production technologies.

2.1.1 THE IMPORTANCE OF INNOVATION IN THE MEXICAN INDUSTRY AND ITS BUSINESS POTENTIAL

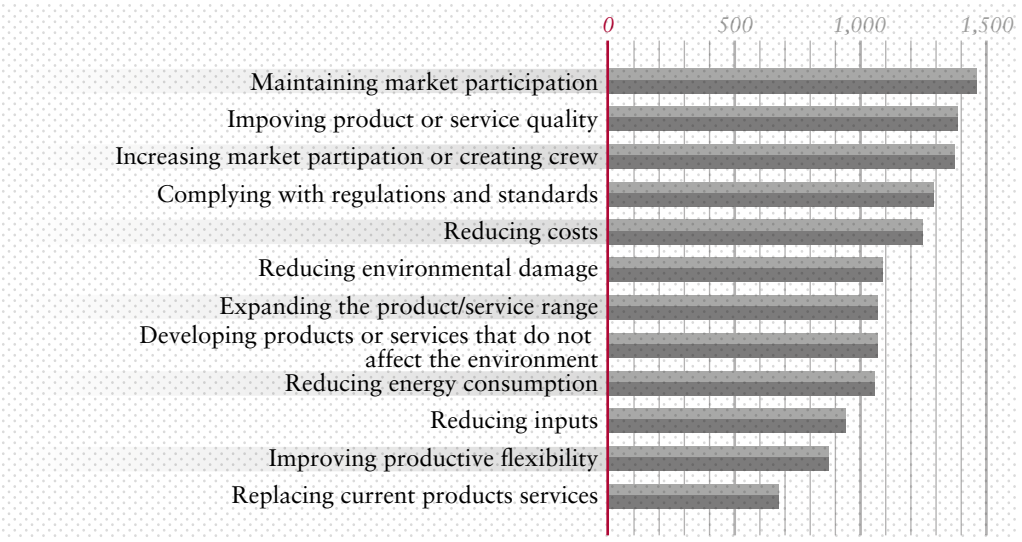
In Mexico, many productive companies consider it highly important to seek to efficiently update their manufacturing processes by adopting technological innovation and industrial innovation trends.

To demonstrate their potential, we address Mexican entrepreneurs' perception of these trends' relevance for their manufacturing processes and services, in order to identify their interests and determine the feasibility of adding them to their short-term strategic plans. This way, we can determine both the market and direct demand for i4.0 applications. We also describe briefly some characteristics of the aerospace and automotive sectors, as they are mature enough to implement i4.0 technologies as "pilot applications" that could, in turn, be implemented in other industries.

The Technological Development and Research Survey (ESIDET), conducted every two years by the National Institute of Statistics and Geography (INEGI), shows the main reasons why industrial companies find it necessary to innovate. In the first place, the survey highlights that companies aim at maintaining or increasing their market share, which they achieve either by producing differentiated products and/or by reducing costs. Therefore, their main goal falls in line with i4.0 trends: applying cyber-physical systems to productive systems, developing more efficient processes, and having useful information to continuously improve each and every level of the value chain. Companies also consider it important to invest in innovation in order to reduce environmental damage and energy consumption. Although these objectives are not related to industrial innovation trends alone, technological applications in digital transformation, intelligent automation or energy decentralization have great potential for Mexico's industry.

Mexican companies interest in having more productive flexibility gains greater significance within a collaborative production ecosystem. This flexibility can be achieved through greater interaction with customers and suppliers, and better integration within the supply chain through IoT and Big Data. This will laid the groundwork to build an intelligent automation infrastructure and to continuously improve the so-called "digital factories".

NUMBER OF COMPANIES IN THE PRODUCTIVE SECTOR THAT CONSIDER THE 2014 INNOVATION GOALS TO BE HIGHLY IMPORTANT



Source: INEGI-Conacyt. Technological Development and Research Survey (ESIDET) 2014 (last available).

2.1.2 THE THREE BIG SECTORS AT THE CUTTING-EDGE OF INNOVATION

In this section, we will focus on three big sectors that, given their importance, penetration and maturity in the Mexican industrial ecosystem, can influence other relevant industries in the country. These sectors are: aerospace, automotive and electronics.

Mexico's comparative advantage based on low salaries —which allowed an influx of foreign capital to several developing economy sectors in the 1980s and 1990s—, is now being replaced by the implementation of new technologies with potential for low cost production of industrial goods, which is also making it possible, to certain extent, to relocate some of the production clusters back to their place of origin[1].

A country's chances to succeed in implementing and participating in the use of these new technologies depends on conditions such as[2]:

- **Relative level of automation in mature sectors (level of labor intensity in certain manufacturing sectors):** the more labor intensive the industry, the less likely robots and automation technologies are to be applied.
- **Exports concentration:** the higher the level of exports concentration, the more difficult to maintain competitiveness based only on economies of scale or agglomeration and, therefore, the more viable the application of new technologies.
- **Productive systems service intensity and diversification.**
- **Availability of telecommunications infrastructure and broadband.**
- **Implementation of public policies fostering technological development and innovation.**
- **Availability of highly-skilled human talent.**

With this in mind, the international industrial sectors more likely to adopt these technological trends are: computers, electronics and optical equipment, transport vehicles, metal-mechanical and advanced manufacturing.

The abovementioned sectors are present in Mexico, especially aerospace, followed by automotive, electrical equipment, machinery and equipment, textile, rubber and plastics, computers, electronics and other products, as well as basic metals industries. The first volume of this book series finds its correlation in this second one, where some of the sectors better positioned to implement these technological trends are analyzed. As pointed out, although all economic sectors are, somehow, adopting —or will be adopting— i4.0 trends in order not to lose competitiveness, currently the sectors mentioned above are more viable to adopt them and, therefore, Mexico's strategies for promotion and international collaboration should focus on them.

We will review some of the main sectors mature enough to adopt i4.0 technologies, analyzing their production chains and capacities, in order to identify their requirements to adopt the most important Fourth Industrial Revolution trends. In doing so, we will be able to address the opportunities for technological development, collaboration and adoption presented by the new production economy.

[1] World Bank (2018), "Trouble in the Making? The future of Manufacturing-Led Development", Washington DC. Available on http://www.worldbank.org/en/topic/competitiveness/publication/trouble-in-the-making-the-future-of-manufacturing-led-development
[2] Idem.

Aerospace

1. Production Chain Analysis

The aerospace industry comprehends the following subsectors: design and engineering; production and manufacture; and maintenance, repair and overhaul (MRO) of aircrafts, helicopters and engines, as well as their parts, components and systems. Its supply chain is comprised of Original Equipment Manufacturers (OEMs), and Tier 1, Tier 2, and Tier 3 suppliers.

In order to meet the demand, aircraft manufacturers (OEMs) need to increase their productive capacity and supply requirements, which opens up the possibility for Mexico to enter the sector's supply chain by fostering the establishment of first tier suppliers in the country.

Therefore, to improve the possibilities of increasing the national value added to the aerospace industry, we need to have the necessary technological and human capacities to carry out design engineering and manufacturing tasks.

2. Technological Capacities

Technological innovations crosscut the entire production chain and range from aircraft design and structural analysis to manufacturing and welding, assembly and quality control, and, finally, maintenance.

Additive manufacturing (3D printing) is one of the most developed trends within the aerospace sector. Companies like Boeing are using around eight thousand 3D printed parts in their aircrafts worldwide. However, it is necessary to continue to make progress in improved production of more precise, more resistant and lighter parts; progress that can be achieved by using polymers, metals and compound smart-materials in 3D printing[3].

In digitalization and IoT, the Mexican company NC Tech has developed a system to instrument and monitor aeronautical parts, as well as equipment and instruments' functionality. This information is reviewed in real time through a cloud-based user interface that can also be accessed from smart phones or tablets.

Out of the more than ten aerospace research centers in the country, the National Center of Aeronautical Technology (CENTA) is well-known for its experiments in i4.0 innovations.

3. Needs and Opportunities

The conditions to attract investments aimed at creating more value-added activities in engineering and design, and, eventually, becoming a driver for research and development activities are set. Proof of this is the fact that the Mexican aerospace industry attracted 51 aerospace investment projects from 44 companies between 2011 and 2015, and that the largest number of jobs —amounting to around 5,000— were created through foreign investment during the same period[4].

The aerospace sector has great potential to implement industrial innovation technologies. Currently, all the parts in an aircraft require monitoring and assessment, both tasks eased by digitalization or IoT. Furthermore, there is an increased need for manufacturing safe aircraft components and parts with minimal error, a better materials weight-resistance ratio, as well as better fuel efficiency.

According to the *2017 Aerospace and Defense Top Management Issues Radar* published by Rolad Berger, 98% of CEOs within the sector consider that the digital transformation of the aerospace sector has or will have an impact within the industry. The document also makes reference to the main technological solutions required by the different stages of the sector's production chain.

Digital transformation processes are of priority for OEM, followed by Tier 1 and Tier 2 companies. In the design phase, there is an interest in digitalization and 3D printing technologies; in production, there is a need for augmented reality, digital solutions for the supply chain, APS, remote monitoring, pneumatic and drive systems, numerical control, robots and cobots; in maintenance, there is a need for augmented reality, remote monitoring and 3D printing for manufacturing spare parts.

[3] Conacyt (Consulted in November 2017). Manufacturing 4.0 in Aerospace Industry Available on http://www.conacytprensa.mx/index.php/tecnologia/tic/18145-manufactura-4-0-industria-aeroespacial
[4] Sergio L. Ornelas Ramírez, VI edition of Mexico 's Aerospace Summit 2016.

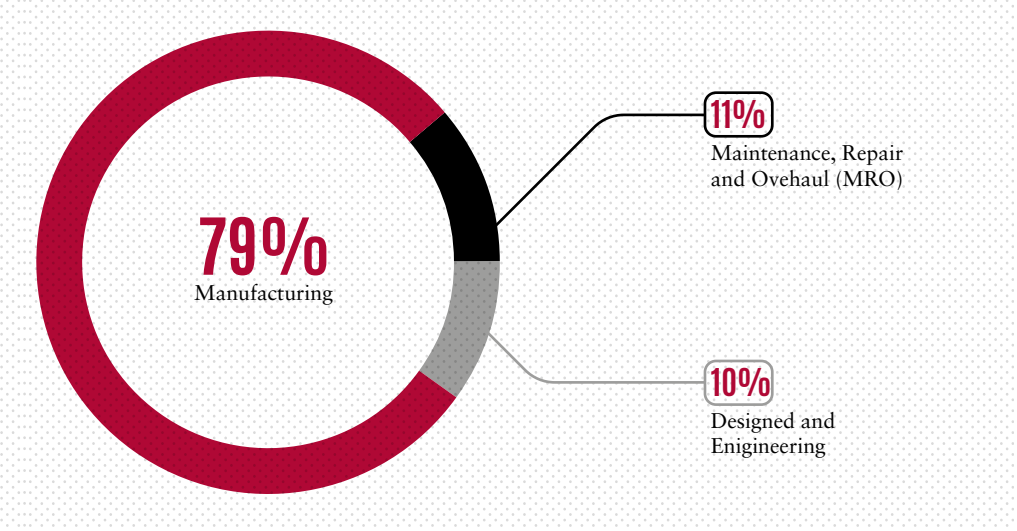
MAIN INDUSTRIAL INNOVATION TECHNOLOGIES NECESSARY IN MEXICO'S AEROSPACE SECTOR

	DIGITIZATION	IOT	SMART AUTOMATION	3D PRINTING
DEVELOPMENT	Simulation in digital environments, virtual prototypes, augmented reality			Use of materials like polymers, metals and compound materials
PRODUCTION	Augmented reality, solutions in the digital supply chain, and APS	Remote monitoring, pneumatic systems, transmission systems	Robots, cobots, advanced numerical control	
MAINTENANCE	Augmented reality	Remote monitoring, for predictive maintenance advanced analysis		Parts repair

Source: Prepared by the author based on Roland Berger (2017) and field studies.

According to the Mexican Ministry of Economy, most companies in the aerospace production chain are manufacturers, accounting for 79% of the total. Thus, and even though adopting all trends is necessary for the aerospace sector, the main opportunities for collaboration fall within intelligent automation, digitalization, IoT and 3D Printing.

PERCENTAGE OF COMPANIES IN THE AEROSPACE SECTOR BY PRODUCTION PHASE



Source: ProMéxico with information from the Mexican Ministry of Economy, 2016.

Automotive

1. Production Chain Analysis

The activities that characterize the finished-product automotive industry range from product origin to final consumer outreach, including design, engineering and development; production of spare parts; component manufacturing; assembly; quality tests; and distribution and sales.

Like in the aerospace sector, the automotive industry supply chain is composed of OEMs; that is, the companies in charge of placing finished products in the market. Likewise, Tier 1 companies are direct suppliers of OEMs and follow strict subassembly parts and components quality, time, and cost controls. Finally, Tier 2 companies supply components to Tier 1 companies, and Tier 3 companies supply Tier 2 companies.

There are over 30 engineering and design centers for light vehicles in Mexico; and 23 OEMs (13 for light vehicles and ten for heavy vehicles) have set up business in Mexico. In the case of auto parts manufacturing, 345 Tier 1 companies supplying major and minor components, and 865 focused on machining, forge and foundry, have been set up as well.

Mexican engineering and design centers study the following:

- Engine pollutants emission reduction. Development of special anechoic chambers, road simulation (detection of parts and bodywork), weather conditions reproduction.
- Engineering, design and development of electronic systems.
- Design and development of new products and components with new technologies, cutting-edge engineering, manufacturing cells and process development[5, 6].

2. Technological Capacities

The automotive industry is one of the sectors rapidly adopting the Fourth Industrial Revolution technological trends. Mexico, one of the major world production hubs, has made great progress in implementing these technologies.

A good example of this is the German company Volkswagen, which is based in the state of Puebla and has started developing augmented reality technology in virtual laboratories, seizing the advantages of the digital transformations.

Likewise, General Motors' On Star service models continue to make progress in IoT, providing Internet connection anywhere their vehicle are[7]. Ford is testing large scale production of automotive parts using 3D printing with the Stratasys Infinite Build 3D printer. Whereas, in 2015, Audi opened in Mexico one of the most important smart factories in the continent. This factory will manufacture digital and automated vehicles.

These examples are only of OEMs and Tier 1 companies. Albeit, the rest of this sector's supply chain is not as advanced in technological innovations and requires both government involvement to encourage technological acquisition and transfer, as well as ProMéxico's help to build relations between Mexican SMEs and technological leaders, to improve their economic development.

3. Needs and Opportunities

According to Siemens, automotive OEMs require different technological solutions. In design, there is special interest in digital technologies for automobiles' design and testing through augmented reality, digital twins and 3D printing; in digitalization, there is interest in engine applications, pneumatic and drive systems and generation of renewable energies, cells and batteries. In production, companies require robots and cobots, mobility systems, as well as solutions for the digital supply chain, with the contribution of different tier suppliers. Last, maintenance and operations increasingly require the use of 3D printing, and implementation of sensors and remote monitoring, mainly for predictive maintenance.

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[5] Ministry of Economy. Automotive Industry Strategic Program (Programa Estratégico de la Industria Automotriz). Available on: http://www.economia.gob.mx/files/comunidad_negocios/industria_comercio/peia_ok.pdf

[6] ProMéxico. (2016). Mexican Automotive Industry: Current situation, challenges, and opportunities. (La Industria Automotriz Mexicana: Situación Actual, Retos y Oportunidades). Available on: http://mim.ProMéxico.gob.mx/work/models/mim/Resource/71/1/images/la-industria-automotriz-mexicana.pdf

[7] Aristegui Noticias (Consulted in November 2017). Revolution 4.0: the new challenge for the automotive industry (Revolución 4.0: el nuevo reto para la industria automotriz). Available on: http://aristeguinoticias.com/2703/mexico/revolucion-4-0-el-nuevo-reto-para-la-industria-automotriz/

MAIN INDUSTRIAL INNOVATION TECHNOLOGIES NECESSARY IN MEXICO'S AUTOMOTIVE SECTOR

	DIGITIZATION	IoT	ENERGETIC DESENTRALIZATION	SMART AUTOMATION	3D PRINTING
DESIGN AND ENGINEERING	Digital twins, virtual prototypes, augmented reality		Efficient storage and renewable energies	Engines, pneumatic systems and transmission systems, autonomous vehicles	Prototypes, materials like plastic, resins, and metals
MANUFACTURING AND ASSEMBLY	Digital supply chain, APS, pneumatic systems, advanced control and mobility systems	Transmission systems		Cognitive robots, cobots	
MAINTENANCE AND OVERHAUL		Sensors, predictive maintenance, advanced data analytics			Parts and auto parts replacement

Source: Prepared by the author based on Siemens and field studies.

As pointed out, Mexico's OEMs suppliers are falling behind in terms of technology (among these suppliers there are those in the plastics, glass, rubber and machining sectors), which entails the creation of new opportunities for collaboration with industrial leaders towards technology adoption.

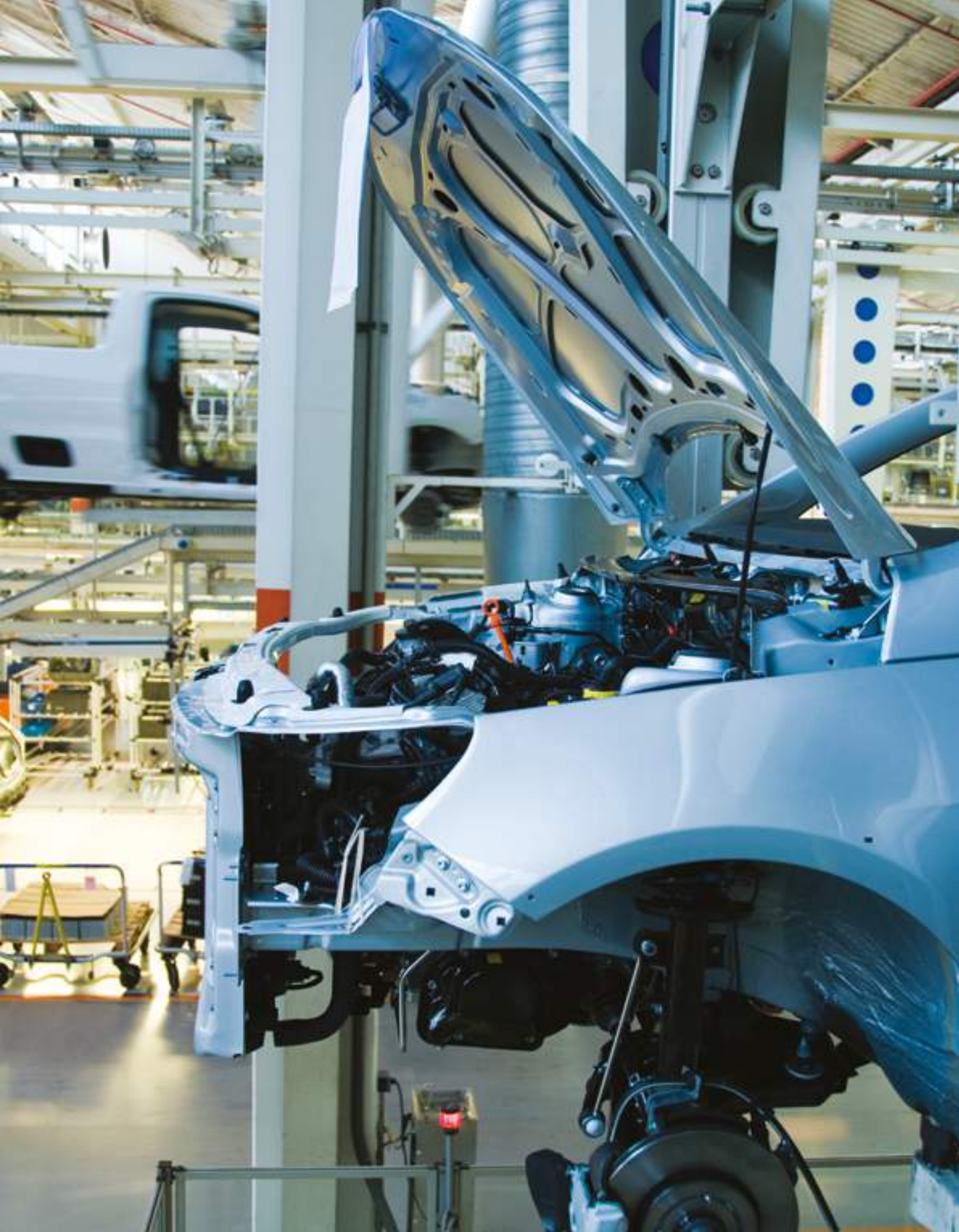
The future of the country's production lies on developing its production chains and increasing its exports value added, which could currently be higher on national participation; therefore, one of the main challenges will be to bring industrial innovation technologies to all the companies across the sector's supply chain, including those for which technology acquisition may be too expensive. In this sense, in addition to the usual collaboration with leading countries and companies in technological production, government support is key to overcoming these barriers.

A current collaboration example is the joint work by German company Siemens and the Mexican government to increase technological innovation and digitalization in the automotive industry (and other industrial sectors) through three main investment areas, technological transfer and training via dual education[8].

The reasons why Siemens considers Mexico to be an appealing market are its investment and industrialization rates, its growing digitalization, and the creation of human capital. According to the company's Regional Director in Mexico[9], these are key times for the industrial sector as it seeks new strategic exporting alliances; hence the importance of developing local chains to support SMEs growth. The abovementioned further highlight the importance of ProMéxico's contribution to achieve greater consolidation between Mexican industrial SMEs, and innovation leading countries and companies.

[8] Siemens News (2017). SEP and Siemens promote technological transfer in industrial processes digitalization and strengthen dual training (SEP y Siemens impulsan transferencia de tecnología en materia de digitalización de procesos industriales y fortalecen la formación dual). Available on: https://w5.siemens.com/cms/mam/press/Documents/2017/100610_Siemens_Final_MoU_Siemens_SEP.pdf

[9] Manufacturing (2017). Siemens and the Government, allies in Industry 4.0 (Manufactura (2017) Siemens y Gobierno, aliados en industria 4.0). Available on: http://www.manufactura.mx/industria/2017/03/06/siemens-y-gobierno-de-mexico-promoveran-la-industria-40



Electronics

1. Production Chain Analysis

The electronics production chain consists of different tiered companies, OEMs and EMSs (Electronics Manufacturing Services), the latter being subcontracted by OEMs. OEMs mainly design consumer and industrial electronics, and are supported by Tier 1, 2, and 3 companies that specialize in printed circuit board (PCB) design, passive and active components, software, and electrical components[10].

The broad electronics industry value added chain comprises different sized companies supplying consumables, parts, and components, but also manufacturing and assembling final goods and other components for the end market.

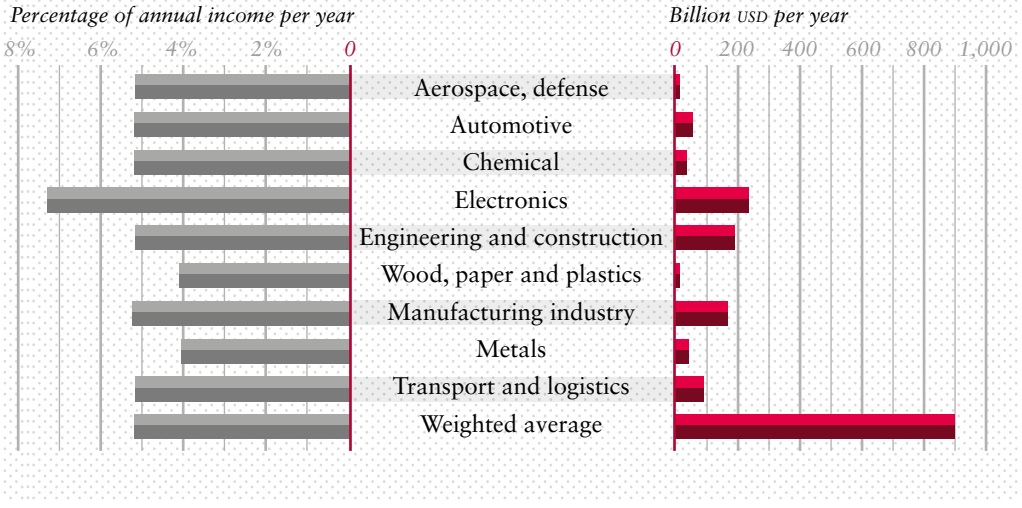
In the case of electronic products, Mexico has a specialized electronics manufacturing industry, mainly of consumer electronic products (television sets, mobile phones and computers). However, national companies dedicated to designing and/or manufacturing electronic components are rare and, therefore, demand cannot be covered. For example, 97% of the components needed to manufacture TV sets in Mexico are imported, which means there are great opportunities for investment[11].

The Mexican electronics industry comprises a wide range of goods, from large electrical and industrial infrastructure equipment, to control devices, engines and light bulbs, among others; note that electrical household appliances, electrodes, or manufactures directly related to the automotive industry are not considered here. Many transnational companies established in Mexico are very much interested in expanding their business in the country, particularly through Mexican companies' productive linkage and by relocating suppliers to close the gaps in the national production chain.

2. Technological Capacities

According to PwC's *2016 Global Industry Survey*[12], the electronics sector expects higher levels of investment in industrial innovation by 2020, rising to 7% of the annual income, whereas, on average, it is estimated to be below 5%.

SECTORS' INVESTMENT IN INDUSTRIAL INNOVATION TECHNOLOGIES



Source: PwC (2016), "2016 Global Industry Survey. Industry 4.0: Building the Digital Enterprise".

[10] Idem.
[11] Idem.
[12] PWC (2016), "2016 Global Industry Survey. Industry 4.0: Building the Digital Enterprise". Consulted on: https://www.pwc.com/gx/en/industries/industries-4.0/landing-page/industry-4.0-building-your-digital-enterprise-april-2016.pdf

In Mexico, and worldwide, the electronics sector shows the greatest development in industrial innovation technologies. This is due to improvements in automation that help to reduce electronic devices mass production costs, but also because industrial innovation technologies have helped to overcome one of its main challenges: the market's demand for ever more customized products, making life cycles increasingly shorter.

At the same time, the Fourth Industrial Revolution brings about great potential for improvement, for even if Mexico is one of the main manufacturers of electronic devices, many of these manufacturing processes are still manual as workers perform some tasks in the production line themselves[13].

3. Needs and Opportunities

The electronics sector seeks to improve its competitiveness through its supply chain linkage, which enables EMSs and OEMs in Mexico to incorporate Mexican component manufacturers to their supply chains whenever possible.

Across the electronics production chain, there are processes with room for technological improvement, as is the case of those related to micro-mechanics. These processes are micro-injection, micro-ceramics, micro-die cutting, and micro-machining, which are used to manufacture active and passive electronic components. Designing new software instructions and algorithms for maintenance and operation is crucial to making industrial processes more efficient. Micro-assembly processes, like Surface Mount Technology, are used to manufacture PCBs, which is the process used to build electronic circuits by welding components directly on PCBs. Surface mounting has substituted "through hole" technology —a method used to install components with wires into the PCB's holes by piercing through the board on both sides[14].

[13] Manufacturing (2017). (Manufactura (2017). La industria 4.0 tiene las 'alas cortas'.) Available on: http://www.manufactura.mx/industria/2017/06/07/la-industria-40-tiene-las-alas-cortas

[14] Ladelec (Consulted in December 2017.) What is Surface Mount Technology? (¿Qué es la tecnología de montaje superficial?) Available on: http://www.ladelec.com/teoria/informacion-tecnica/407-que-es-la-tecnologia-de-montaje-superficial-smt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2.1.3 MAIN FINDINGS

According to their monetary value, for each one of the analyzed trends Mexico is an important, growing market, with multiple opportunities for doing business and building alliances with industrial innovation technology leaders that will boost the country's economic development.

Companies established in Mexico consider these innovation goals important, as they allow them to increase their market participation, reduce costs as well as environmental damages and energy consumption, and have more productive flexibility.

Regarding Mexico's current industrial innovation technology capacities, even though they vary from sector to sector, there is currently a higher development in 3D manufacturing, industrial components and molds with certain dimensions and weight; IoT with applications in controlling, monitoring and maintaining final goods or components within assembled products; and digitalization, having even some digital factories in the country.

In the analysis performed, three of the main industrial sectors (aerospace, automotive, and electronics) have been found to possess certain strengths that will allow them to adopt these industrial innovation trends; strengths such as: expertise and productive capacity to develop certain productive processes —which vary from sector to sector—, and a significant number of OEMs —many of them international companies operating under global standards—, research centers and academic institutions where technological and human capacities are developed, mainly in fields such as industrial/mechanical, mechatronics, systems and IT, and graphic and industrial design —although, as mentioned before, there could be more courses in advanced technology, including robotics. Based on these strengths and experience, Mexico is well-positioned to build alliances with world leaders in industrial innovation.

On the other hand, some common needs include the lack of development in certain suppliers' specific production and design processes, as well as the lack of productive and technological capacities in SMEs; therefore, there are different opportunities for collaboration in order to strengthen the production chain.

At the public policy level, there are strategies and programs aimed at new products and processes for enhancing energy efficiency, as a result of the Energy Reform and the International Agreements underwritten by Mexico to reduce greenhouse gases and other pollutants. However, there is no explicit policy in areas such as automation and robotization —which do exist in countries like the United States and Japan— or the IoT and 3D Printing; therefore, it is necessary to develop public policy instruments to develop these technological trends and implement them in Mexico's industries.

2.1.4 COLLABORATION OPPORTUNITES IN MEXICO'S BIG SECTORS

Pursuant to the findings covered in previous sections, we have identified some opportunities for collaboration in Mexico, where joint collaboration and synergy between government, industry and academia with world leading countries are key.

Through the analysis of this group of outstanding Mexican industrial sectors ripe for adopting industrial innovation technologies, we have divided the opportunities for collaboration into two strategic axes: strengthening the production chain and developing technological capacities and working skills.

To strengthen the production chain, it would be necessary to develop national and international suppliers with industrial innovation capacities, and to strengthen OEMs and different Tier companies' productive activities through the application of technological trends.

With regard to the development of working skills and technological capacities, the goal is to train the human capital required to apply innovations and conduct a higher level of research and technological development that will enable more value added to be added to areas related to industrial innovation.

The main opportunities for collaboration in the sectors analyzed are shown below, taking into account that these arguments should not be regarded as a limit, but rather as guidelines to

make better use of each sector's strengths according to their needs and particulars. Firstly, we will cover matters related to the production chain; and, secondly, working skills and innovation initiatives developed via R&D.

Aerospace

1. Strengthening the Production Chain

- **Attracting aerospace companies operating with industrial innovation technologies to create local supply for processes that are not yet developed in the country to support OEMs and Tier 1 companies' production increase.**

  The sector seeks to increase the national value added in the engineering and design phases, as well as decrease its dependence on certain components' imports. At the moment, there are few national and foreign companies at this stage of the production chain, therefore Mexico could foster their development through foreign investment by aerospace companies using technologies such as augmented reality, digital twins, or 3D printing, which are used in activities such as simulation, molds creation, scenario simulations, and prototype manufacturing.

  Similarly, we seek to decrease dependence on molds and tools imports, therefore, it is necessary to attract investment from companies specialized in these processes and that are currently using 3D printing technologies, as this type of technology would enable to manufacture tools in a quick, low-cost, customized way, and with adequate physical characteristics such as weight and size thanks to the new materials and technologies used in additive manufacturing. The United States and Germany are Industrial leaders in this sector.

- **Collaborating with technological leaders to develop MRO centers with industrial innovation technologies in Mexico.**

  There are some companies in Mexico that specialize in MRO, located mainly in the state of Querétaro. Due to the increasing global demand for aircrafts, passengers' safety, and the aerospace sector's need to reduce time and costs, it is necessary to count with MRO centers that use industrial innovation technologies such as robots, sensors, data analytics, 3D printing or digitalization. Mexico could collaborate with industrial innovation leaders like the United States, Japan or Germany to develop its MRO centers, incorporating and experimenting with these technologies, based on industrial processes and their quality standards, to create world leading MROs.

- **Consolidating OEMs and local suppliers' productive capacities through the incorporation of leading industrial innovation technologies.**

  This first opportunity is to consolidate Mexico's global competitive advantage in turbine manufacturing with Mexican aerospace OEMs and Tier 1 manufacturing and production companies through the incorporation of industrial innovation technologies in IoT and 3D printing —an industry led by the United States, Germany and Singapore.

  The second opportunity revolves around strengthening of the supply chain of parts, components, materials and equipment for companies that are already established in the country, by generating digital supply chains, helping to shorten aircraft manufacturing and assembly time and costs, collaborating with digital leaders to implement digital supply chains and offer technological solutions like Big Data and Cloud Computing.

2. Labor and R&D Development Capacities

- **Collaborating with international leaders to develop research centers or laboratories specialized in aircraft design that use industrial innovation technologies.**

  One of the country's main challenges in creating more value added is to develop design-specialist human and technological capacities. Mexico has some aerospace research institutes, but few of them specialize in design.

To foster technological development and research, we suggest collaborating with international leaders who use industrial innovation technologies in aircraft design —such as AI, digital twins, development of new materials, new 3D printing technologies and energy efficiency— to establish research centers or laboratories in Mexico, equipped with these technologies and the qualified staff needed to use them. This will position the country as a world leader in aerospace design.

Querétaro and Sonora are some of the states that can host these design laboratories or research centers in collaboration with innovation leaders.

- **Collaborating with innovation leaders to develop educational offering, curricular content, and standards and certifications in industrial innovation technologies applied to the sector.**
  According to ANUIES, there is a total offer of 25 graduate and postgraduate courses related to the aerospace sector.

  To secure the current and future development of the aerospace sector, it is vital to have human capital with the necessary capacities, competencies and certifications to work within i4.0 ecosystem.

  Our human capital can be increased through collaboration agreements among government, businesses and academia from leading countries to adjust the curricula, train teachers overseas, and create standards and certifications to regulate the use of these technologies.

Automotive

1. Strengthening the Production Chain

- **Attracting and establishing international companies that manufacture farts for die-cutting and/or stamping, machining and foundry and have experience implementing industrial innovation trends.**
  The adoption of these industrial innovation trends by Mexican companies is not mature yet. The cases reviewed in this study show examples of pilot projects; that is, positive innovation experiences that have not been implemented at a mass production level and have not substituted current processes.

  Attracting and setting up companies with industrial innovation trend-based ecosystems will provide the necessary information about the experience of joining the national production chain, and, thus, it will be possible to document the challenges and opportunities that arise, and create an incubation and development model for the technologies implemented in domestic companies.

  As mentioned in chapter two, Tier 2 and Tier 3 companies offer plenty of opportunities in the Mexican automotive sector. Learning from the experiences of international manufacturers will boost the current capacities of domestic manufacturers and will generate an experience-based model for technological adoption that can be replicated.

  The experience of manufacturers using additive manufacturing to replace spare parts and auto parts will provide feedback on product precision, inventory reduction, and responsiveness to real time demand.

  In the case of manufacturing and assembly processes, attracting manufacturers that utilize collaborative robots will help to design and implement training models for the labor force.

  In the case of stamping and machining parts manufacturers, using software to integrate the different production stages will help to measure its impact on product precision, as well as their incorporation into the domestic supply chain.

- **Creating a structure of technological transfer from industrial innovation leading countries to Mexican manufacturers.**
  The Mexican auto parts and finished-product automotive industries have plenty of experience in their fields and are well-known worldwide for their high quality standards.

Mexico has the necessary capacities to develop a pilot project where research centers and supply chain companies become incubators for industrial innovation technologies. Detailed below are the expected outcomes for this project:

- Research and development centers: integrating additive manufacturing technologies to the design of low-complexity auto parts will offer greater modeling precision, and the possibility of obtaining information that will help to reduce printing time and increase production levels.
- Using digital twins will allow manufacturers to test auto components in different surfaces and at different temperatures to measure their wear.
- Stamping and machining factories: adopting the IoT has resulted in cost reductions, more vertical and horizontal integration of production processes, and greater accuracy when manufacturing parts.
- Assembly factories: Using augmented reality has proved to be a useful tool to facilitate workers' tasks by assisting them in real time through mobile devices.
- Using collaborative robots has improved product quality, reduced labor risks, and increased assembly automation.

2. Labor and R&D Development Capacities

- **Creating the state of Guanajuato Technological Research and Development Center.**
The state of Guanajuato has a significant participation in the domestic number thanks to the number of productive plants (15%), supplying companies (13%), and light vehicles production (22%.) it is home to.

  The states of Puebla, Mexico, Aguascalientes, and Querétaro have important design and engineering centers, such as the Center for the Development of the Automotive Industry in Mexico (CEDIAM) in the first three states, and the Technical Assistance and Research Center (CIATEQ) in the latter. However, there are no research centers in the state of Guanajuato.

  Therefore, creating a Technological Research and Development Center will help to better link the industry and the academia.

  The center's objective will be to foster specialization in industrial innovation technologies applied to Mexico's largest parts production processes; such as smart machining, stamping, and industrial additive manufacturing.

  Likewise, it will be a space for mutual collaboration among assemblers —such as Mazda, Honda, General Motors, and Volkswagen—, from Japan, the United States, and Germany, all leading countries in industrial innovation.

- **Joint work program to incorporate or strengthen technical-technological innovation competencies in academic offerings and higher education curricula in the northern-central region states.**
Guanajuato, Aguascalientes, and Querétaro are home to 32.5% of the productive facilities, 37.7% of the supplying companies, and 37.9% of the light vehicles production in Mexico; however, between 2012 and 2016, only 12% of all domestic graduates in the eight available courses graduated in these states. By incorporating the states of Nuevo León, Coahuila and San Luis Potosí to the region, its participation increases to 57.5%, 68.7% and 55.8%, respectively —that is virtually more than half the productive capacity of the automotive industry. However, the number of graduates from related courses only increases slightly, from 12% to 16.4%, representing 1,251 young graduates, less than the 1,399 graduates from Estado de México and the 2,292 from the state of Puebla.

  Against this context, we propose —as an opportunity for collaboration— to create an interinstitutional program that, together with national governmental agencies, representatives of the automotive industry, and the leading countries in industrial innovation, would help to identify the technical-technological competencies related to the automotive industry in order to adjust or enhance the study programs at a national level and with special emphasis on the country's North-central region.

Electronics

1. Strengthening the Production Chain

- **Creating local narrow-band IoT (NB-IoT) networks in the Northwest, Northeast, and West areas of the country.**

  Mexico has valuable expertise in public areas connectivity thanks to an important broadband network supported by the scheme Connected Mexico (México Conectado). The scheme's main goal is to provide academic and research centers with proper connectivity.

  Likewise, the Northwest, Northeast, and West regions are some of the country's industrial development hubs. Given of their proximity from each other, the cities of Ensenada, Mexicali, and Tijuana in the Northwest region (Baja California); Saltillo, Ramos Arizpe, and Monterrey in the Northeast (Coahuila, and Nuevo León); and Guadalajara in the West (Jalisco) have great potential to form economic units, generate human capital, and conduct research relevant to the electronic industry.

  For all the above, collaborating with countries like Singapore in connectivity matters, and with China, through an Industrial Internet Alliance, to further explore the concept of industrial Internet, would speed up the link between smaller and medium-sized cities to narrow the city-countryside gap. Both collaborations would allow the development of different pilot projects to implement local narrow-band IoT (NB-IoT) networks in the Northwest, Northeast and West regions of the country. For example, the city of Guadalajara would then be part of multiple current IoT strategies, such as the Smart Cities Cluster (Clúster de Ciudades Inteligentes), and Creative Digital City (Ciudad Creativa Digital).

- **Creating a structure for technological transfer from industrial innovation leading countries to manufacturers in the states of Baja California, Jalisco and Tamaulipas.**

  Mexico's expertise in manufacturing components and semiconductors, medical equipment, communications equipment, computers, and office equipment is located mainly in the states of Baja California, Jalisco and Tamaulipas, as these states are home to many important manufacturing companies, as well as main recipients of FDI and purveyors of a top academic offering.

  These states' expertise can help Mexico to become an ally of the United States to manufacture the necessary equipment for the IoT industry, through joint investment in Mexican plants under joint ventures schemes with US companies,given their global leadership in IoT, their geographical proximity, and their status as main domestic electronics manufacturers.

  Thus, Mexico would become an experimental laboratory for the mass production of IoT measuring sensors, smart networks, data processing mobile electronic devices, and components and semiconductors.

2. Labor and R&D Development Capacities

- **Creating a technological research and development cluster specialized in the IoT, in the state of Jalisco.**

  Jalisco has a significant national participation in economic units (10%) and, in 2016, was the leading state in FDI attraction (20%). It also has more than 33% of the production in the sector among other Mexican States. It is home to important research and development centers —such as Intel / Jalisco that specializes in Telecommunications— as well as a branch of the Center for Research and Advanced Studies of the National Polytechnic Institute (Cinvestav).

  The state has designed a project called "Digital Creative City" for Guadalajara, with the objectives of turning it into a smart city, boosting audiovisual equipment production, and using new digital technologies as communications and connectivity solutions[15]. Additionally, it has the largest number of graduates in the country, followed by Mexico City, with more than 2,500 young graduates 2016.

[15] ProMéxico, (2014). Internet of Things (IoT) Roadmap. Available on: http://www.ProMéxico.mx/documentos/mapas-de-ruta/internet-of-things.pdf

For all these reasons, creating a Technological Research and Development Cluster specialized in the IoT will reinforce the link between industry and academia and focus its work on IoT technologies.

This cluster will foster joint collaboration between the main companies present in the state: Lucent Technologies and Tyco Valves and Controls of México (electronic components manufacturing); Freescale and Intel (semiconductors); Benchmark Electronics, Sanmina SCI, Flextronics, Jabil, and Universal Scientific Industrial, Gollet Electronics, Eei, Dyseme, Gartin Technologies y Pounce Electronics (manufacturing); as well as HP (computer equipment)[16].

Collaborating with the United States world leading research centers will allow Mexico to draw on from their expertise in this area and the use of technology in key productive processes; whereas in electronics, energy, and potential creation of smart cities.

- **Strengthening the higher education sector by creating IoT study programs and integration relevant competencies and skills.**

In Mexico, young students graduated from electronics related courses, and over 66,000 graduated from systems and IT programs. This translates into opportunities for further specialization in industrial innovation technologies.

Designing and adding courses on IoT to current study programs will provide the necessary specialization of Mexico's labor force to facilitate their integration into factories operating under industrial innovation ecosystems.

This opportunity for collaboration focuses on creating an interdisciplinary work group where Mexico will participate, together with its American counterparts, as leader in IoT.

This collaboration group would be formed by governmental agencies responsible for training and specialization, Mexican and American universities and research centers, and emblematic technological development multinational companies such as CISCO, IBM, Intel, General Electric, Google, Microsoft, and Oracle.

The goal will be to update and professionalize the current IoT curricula; create new technological training courses, both on software design and hardware development; increase graduates technological adoption and expertise; and create specialization and postgraduate offerings with academic transfer links.

[16] ProMéxico. Electronic industry. Sectoral evaluation. Available on: http://www.ProMéxico.gob.mx/documentos/diagnosticos-sectoriales/electronico.pdf

2.2 MEXICO'S INNOVATION STRATEGY

Disruptive technologies have the capacity to transform the way in which different activities are conceived and carried out; such as, production processes and services within enterprises. As we have seen, i4.0 trends are changing the productive ecosystem in sectors that develop high and medium technology, giving new value added to traditional production chains.

In this second section, we will highlight some of the trends relevant to i4.0; either as enablers or for direct application. Firstly, we will discuss Mexico's collaborative strategy included in the i4.0 road map as its guiding principle. Secondly, we will discuss different strategic lines for innovation in those technologies that will enable digital transformation; such as cyber security, IoT, and IT. In addition, we will discuss innovation in technologies across high value sectors, where Mexico is promoting a long-term strategy to develop the necessary human talent and capacities to participate in collaborative projects with world leaders in industrial innovation, as is the case of the space, aerospace, and logistics industries. Finally, we will mention some complementary technologies, such as optics and photonics, which are related to telecommunications, security, data collection, and automation, among others.

These strategic lines show a Mexico with vision and commitment. A Mexico with innovation capacities, a long-term goal, and the willingness to actively participate in the digital transformation of a new production economy. Thus, it brings to the table the current maturity of its industries, the development of new applied technologies, and its human talent to lay the foundations for new international alliances, projects, and business, in order to accelerate the modernization of the new global value chains.

2.2.1 PRODUCTIVE ECOSYSTEMS OF THE FUTURE

Industry 4.0 (i4.0)

The beginning of the new decade has marked a turning point in what we now call the digital era. Breakthroughs like the IoT, the analysis of big and thick data, the digitalization of services, and real-time digital collaboration, have started to influence the different production systems. These advances hold out the great promise of continuous and exponential economic development, which will, in turn, translate into greater comfort.

In this Fourth Industrial Revolution, we are facing a new technological archetype that combines the digital, the mechanic and, even, the biological to achieve unprecedented productive efficiency and develop endless new products and services. The pool of possible technological applications of the IoT, the Internet of Services, and automation in i4.0 gives way to the idea of highly-interactive smart factories; as well as to the possibility of developing hyper-flexible manufacturing techniques, able to adapt to both industry-specific needs and process-specific requirements. In consequence, this new archetype's benefits become tangible —from concept and design, to production and marketing, as well as costs, productivity and responsiveness to market changes.

To facilitate the transition of current productive models to i4.0, industries must prepare to implement the emerging digital transformation trends. For example, data analysis and predictive algorithms make it possible to reduce production costs by 3.6% per year. In fact, these advances present the industry with a positive outlook, as they are expected translate into over 907 billion USD in investment by 2020, creating new large-scale business opportunities.

Mexico must prepare to incorporate these innovations into several of its industries, especially those in the manufacturing sector. Should they manage to adopt these new trends, businesses could benefit from the new productive ecosystem and increase the value offering of their activities. Otherwise, they could find themselves obsolete. Currently, several Mexican productive sectors have the necessary capabilities to transition into this new ecosystem and there are many mature niches that have already incorporated i4.0 practices thanks to foreign investment in industries such as automotive,

aerospace, and electronics. Technology transfers have allowed factories to attain high digitalization levels, where the IoT, data analytics, and collaboration with robotic systems, among others, are paving the way for other domestic industries to follow their lead in their own sectors.

As part of these efforts, Mexico seeks to create two hyper- flexible manufacturing clusters by 2019 and 2021. The goal is to lay the foundations for a thorough implementation of the i4.0 framework in manufacturing operational systems so that it becomes an example of the application of these technologies in advanced manufacture. To support these projects, an i4.0 maturity model is being developed, in order to identify and catalogue the current situation, needs, and basic steps to follow to transform each and every industry. Besides, the manufacturing sector "triple helix" is carrying out negotiations for clusters to achieve a high level of integration among the companies and bodies that conform them. Their goal is to create more value added, following the example of companies like Continental and Volkswagen, and to develop a collaborative environment among academia, the private sector, and the government (all the three parts of the triple helix) to develop industrial innovation projects.

Several working groups with government, academia, and industrial representatives have set the objective for Mexico to be among the top ten countries in the Harvard and MIT's Economic Complexity Index by 2030. To achieve that, a strong technological implementation (both in industry and in daily life), R&D&i networks, the adoption of processes, and an increase in the IoT market are necessary. It is the commitment of all national players to implement these disruptive technologies through the research, development, adaptation, and management of innovation projects.

It is necessary to foster interaction of these new technologies and innovations with other areas and disciplines, as this interaction will be beneficial to sectors such as health, education, the environment, and society in general. That is, issues like interconnectivity, urban operating systems, prediction models and systems, more efficient resource management, and others, that will bolster an innovation-based circular economy.

Cyber Security

The larger the digital transformation process, the bigger the vulnerabilities related to cyber systems and devices. On average, cybercrime costs the world economy 575 billion USD a year, which is equivalent to 0.5% of the global GDP, and increases every year. Therefore, we are continuously looking for new ways to reduce crime and vulnerabilities and create a secure environment to foster the adoption of digital solutions in different industries.

In the past five years, the Mexican cyber security market has diversified thanks to a large variety of competitors. Several transnational companies operate in Mexico and lead the industry largely thanks to the digital solutions they provide. Among them, we can highlight IBM with offices in Mexico City, Guadalajara, and Monterrey, more than 4,500 employees, and sales for over 550 million USD a year, offers cloud computing, cyber security, and data analytics services. Microsoft, another leading software and security provider with offices in Mexico City and Nuevo León, offers Hexadite applications that provide cyber security services to Latin American financial and service companies. Intel and Cisco, also based in Mexico City, are renowned for their work in developing cyber security software and services for Mexican companies.

The Mexican government has developed strategies and passed regulations to spread the digital transformation across the country. To that end, it promotes the Computer Emergency Response Teams (CERTs) / Collaborative Research into Threats (CRITs) and Computer Security Incident Response Teams (CSIRTs) certifications in international cyber security standards. Moreover, it has created the National Cyber Security Strategy and the Cyber Security Council, as concrete actions geared mainly towards the medical and financial sectors, which were the target of most of the recorded cyber-attacks, and in e-commerce and industrial services.

Recently, ProMéxico published an analysis of the current situation of the country in the face of global cyber security trends, as we are aware of its key role in the transition towards new collaborative and i4.0 business models. One of the main findings was that many analysts consider Mexico to be a strategic platform for technological implementation and digital services development Latin America, as the main information technology (IT) leading companies have set up their continental headquarters

in Mexico. Cyber security is in high demand, as more and more industries are planning to adopt i4.0 technologies to improve their processes; thus, out study recommends creating IT clusters to foster the digital ecosystem by integrating industrial services and application systems.

In the short term, it would be advisable to promote a cyber security collaborative strategy with government, industry, and academia participation —such as the National Cybersecurity Strategy—, which serves as a directive that helps to guide a long-term vision for a digitalized Mexico in a world that is increasingly more connected. In this way, the adoption of these technologies will be accelerated, improving the country's competitive offer in terms of human talent, industrial innovation, and research and development; thus, becoming an attractive ally for developing new businesses within these digital trends.

Internet of Things (IoT)

The term of Internet of Things (IoT) was coined by the Massachusetts Institute of Technology (MIT) in 1999. It refers to the digital interconnection of daily objects through the Internet, and its massive use is reflected in its future application by most industries and business environments.

According to experts, in 2020, there will be around 26 billion devices connected to the IoT. Latin America is expected to have massively adopted this trend by then, and Mexico is regarded as the better positioned country to profit from it, since, according to data from the Organisation for Economic Co-operation and Development (OECD), Mexico will grow from its current 8 million connected devices, to 200 million by 2020.

In consequence, in 2014, ProMéxico, together with several players from the triple helix, promoted the creation of a national strategy road map, which resulted in a document that not only reported on the sector, but that also provided a SWOT analysis and mapping of the arguments and analysis drafted by each of the players. Likewise, the most relevant trends were analyzed, helping to lay the foundations for suitable planning. In view of all this, we drafted a strategy based on two milestones and their corresponding projects:

Milestone 1
Mexico as an IoT applications model for Latin America regarding design, advanced manufacturing, product development, and new IoT business and service generation.

Projects:

- Creation of infrastructure (cloud computing, Big Data, telecommunications, among others) to design and develop IoT applications.
- Development of a network of spaces such as Fab Labs / Living Labs / Tech Shops.
- High technology incubator to promote new IoT business generation.
- Building of academia-industry collaboration mechanisms to provide engineers and technicians with more relevant training.

Milestone 2
Mexico among the top five digital solutions and Big Data management leading countries by 2025.

Projects:

- Development of an IoT-specialist support scheme.
- Design of a Big Data and IoT specialization in strategic regions (Guadalajara, Monterrey, Querétaro, Mexico City, Puebla).
- Creation of a world-class national IoT cluster network under the smart regionalization model.

Currently, the Mexican government seeks to continue to foster businesses' competitiveness, productivity, and specialization in key and future economic sectors by integrating IoT technological platforms.

Information Technology

The information technology (IT) sector is part of all industries and our daily lives worldwide. Its direct role in the digital transformation of businesses and society's day-to-day functioning has had a disruptive impact on the way we interact with our immediate environment.

Likewise, global social, political, economic, environmental, and technological trends converge to bolster the IT sector development in the years to come.

As already stated, all industries are facing unprecedented changes in terms of implementing new business models, adopting flexible and automated operating processes, developing tailored products and services, utilizing new channels to grab the attention of and expand into new markets; and, in general, integrating different elements of technological innovation and digital disruption to their operations, which the IT sector understands to be part of i4.0.

During the past decade, Mexico has become one of the most competitive services exporting countries and has attracted investment for the IT sector; several states, such as Jalisco, present optimal conditions to compete in the arena of global businesses.

For this reason, several players of the triple helix in the state of Jalisco, together with ProMéxico, have promoted the elaboration of a strategic roadmap to help to maintain the sector's growth, but, above all, to reach its full potential in line with global market trends, and a long-term vision.

The strategy for the sector's development is based on three milestones integrating very specific projects that will help to attain its short- and medium-term goals; always linked to the available human talent and the training needs, and with Mexican businesses' intellectual property and, of course, the sector's sustained growth.

The state of Jalisco's IT sector's roadmap represents a turning point in a long planning and implementation processes, focused on high-impact actions that will translate into business leads for the country. Technological based companies are expected to become more efficient, and in turn, reduce costs and their impact on traditional sectors.

Current IT developments will allow Mexican companies, especially those in manufacturing, to transition from digital to smart applications, and adopt artificial intelligence, automation, and security.

Aerospace

The global aerospace industry has evolved quickly in the last years, thanks to the introduction of new technologies —a trend that, with no doubt, will continue to grow.

This fast evolution has created an important market for aircraft and aircraft materials and components manufacturers, as well as for technology developers and research centers.

All these players have discovered Mexico's advantages in the advanced manufacturing global landscape, as well as other important virtues such as its geographical location, its natural resources, its qualified labor force, and its preferential access to important markets, among others.

In this national reality, Mexico has for many years taken decisive steps to position itself as one of the main manufacturing centers, with growing participation in the sector's exports every year.

Mexico is, no doubt, a strong player in the global aerospace sector, with many short-, medium-, and long-term opportunities, given the global aerospace market growth prospect.

This new paradigm of competitiveness is underpinned by the regions' capacity to attract and retain talent and investment; for this reason, and based on its vision of growth, in 2015, ProMéxico supported the design of a national strategy called *National Flight Plan* (Plan de Vuelo Nacional), and a regional capacities strategy for the states of Querétaro, Baja California, Chihuahua, and Nuevo León —and soon Aguascalientes—, which are renown Mexican industrial hubs, in order to contribute to the development of a highly-competitive sector with an international outlook. These strategic documents are the result of a joint effort, and their main three accomplishments are:

- Helping to obtain the agreement and coordination of the necessary institutions to implement the strategies.
- Helping to mold the business environment to attract more investment; their importance lies in the trust they have inspired in the community of investors interested in the aerospace sector,

by conveying a clear vision for development and the commitment of the country's public and private institutions to address the areas where Mexico is not competitive yet.
- Generating interest in the promotion of policies that help to yield more benefits for foreign investment, in order to become more competitive in the global economy and achieve better social and economic development in Mexico.

Currently, Mexico's aerospace sector is comprised of more than 330 companies, seven clusters, and at least 18 research, development and training centers. This places the country as the seventh supplier of aeronautical parts to the United States, over Italy, Singapore, Korea, and China, and among the world's main suppliers.

Mexico's challenge lies in becoming ever more competitive, identifying new business models based in i4.0 manufacturing, and the global digital era.

Space Industry

The space industry has been in constant evolution and transformation, growing from a simple geopolitical positioning tool to an instrument that improves people's daily lives in areas as diverse as education, medicine, and climate, among others. This growing commercial demand for space applications and services has encouraged technological innovation, making them more accessible.

Mexico's position in the space sector has been strengthened by the Mexican Space Agency, which has undertaken activities related to climate change, natural disaster prevention, Earth observation, and other satellite services such as geographical information systems and global navigation satellite systems (GNSS).

A thorough analysis of Mexico's strengths and opportunities, included in the roadmap titled *Orbit Plan 2.0* (Plan de Órbita 2.0), has led us to conclude that the industry must incorporate new space technologies focused on citizen services and security. With this in mind, Mexico has drafted four thematic axis to develop the Mexican space industry:

1. Innovation and opportunity niches for the industry and converging services (Earth observation, civil protection).
2. Self-determination in developing space activities and cooperation to strengthen the Mexican space sector.
3. Boosting of the sector's value chain and industrial development.
4. Promotion of digital access and development of applications and solutions.

In view of all this, players of the triple helix have drafted four strategic milestones, based on their vision for the Mexican space race towards 2036. These milestones help to create a national strategy for this sector's development.

In the first place, by 2035 Mexico is expected to hold 40% participation of the global share market, especially in population assistance, climate change, and educational applications by strengthening the National Space Standards Technical Committee as the organism tasked with developing specialized strategies for strategic markets. Also, we will seek to secure access to space, broadening orbital resources, and access to the radioelectric spectrum. To achieve this, it is essential to create venture capital investment group networks, focusing on infrastructure projects, laboratories, and coordination and planning bases.

On the other hand, we will seek a competitive participation in the space components, products and services market of 1% (currently, about 3 billion USD) by 2026. In addition, Mexican space infrastructure is expected to increase by 25% for Latin America, integrating applications of the communications system for national security and the development of space ports, positioning Mexico as the regional leader.

The high priority of development and incubation of new niches in the space market is an opportunity for Mexico. We must generate the industrial, scientific, educational, and innovation capacities necessary to explore and strengthen Mexico's position in markets such as satellite observation and its climate change applications, early warning, national security, farming, and resource

management, i4.0 integration, hardware and software design of space platforms and components, and health and education applications.

Logistics

Logistics comprehends diverse, essential elements for the efficient trade of goods, which is important for a country's growth and competitiveness.

Currently, and especially in the case of global supply chains, geographical distance is less of a problem, whereas inefficiencies are an obstacle for business links between countries. For this reason, it is necessary that all aspects pertaining to logistics, namely infrastructure, information exchange, and the operational side of management and product storage, foster the development of commercial activities.

In this scenario, Mexico has the potential to become one of the main players in global logistics. Its privileged geographical location, as well as the human talent available in a far superior degree than in most mature economies, as well as its outstanding capacities for sophisticated productive activities in design, engineering and manufacturing have helped it stand out in, for example, the automotive and aerospace industries. However, its performance in logistics has room for improvement in the short-, medium-, and long-term.

In that sense, and in order to improve the efficiency and competitiveness of Mexican logistics, ProMéxico has fostered the development of a national strategy, designed with the participation and cooperation of experts in the field of domestic logistics, and from other Mexican industries that are highly sensitive to logistics efficiency, government institutions, and academia. Together they developed the *National Logistics Roadmap*.

This document outlines Mexico's strategy based on two milestones, and its corresponding large projects and actions. On the one hand, it seeks to join efforts in developing the logistics sector; and, on the other hand, successful integration is sought for all the necessary elements and players to cooperate efficiently, creating new working systems, incorporating international best practices, developing high value-added services, and generating, together with other important industries for the country, more capacities that will benefit both the domestic market and international trade.

Mexico's conditions and capacities are ripe to transform the logistics sector and improve its performance. Currently, there are new market trends that are changing the way supply chains are organized and structured and revealing new business models making greater use of artificial intelligence, product customization, autonomous logistics by using drones and robots, as well as implementing cloud-based logistics and using Big Data.

A good example is the increase in e-commerce, where logistics play a key role, as it requires developing predictive logistics that will, in turn, create greater efficiency and reduce costs.

Undoubtedly, the steps that will place Mexico to a competitive position will best serve the domestic market from the point of view of logistics, and also help it become a world hub.

Optics & Photonics

The 2016 roadmap titled *Towards a Brighter Mexico* covers both research and the commercial application of a sector that is an advanced technology enabler. The goal is to trace a highly efficient and viable roadmap for the development of a favorable national ecosystem for optics and photonics. Thus, we have conducted a deep analysis to then propose high value projects, as part of a solid medium- and long-term strategy to create a stable ecosystem for the sector's development, as well as triggering the participation of Mexico's industry in photonics.

The first milestone entails the creation of a National Photonics Cluster and the Mexican Photonics Initiative, a center for research, production, and promotion of photonics and optics in Mexico, which is actually planned to be developed in Querétaro, very close in distance and integration to the aerospace and automotive clusters, thus strengthening the innovation strategy of the region. Hence, it will be possible to conduct new studies to strengthen the value chain and supply of photonic materials, bolstering the business ecosystem to develop logistics and a solid specialized certifications infrastructure.

The second milestone will seek to renew the country's energy production through an innovative renewable energy system. To achieve energy efficiency through photonic technologies, there will be incentives for investment in companies developing advanced photovoltaic cells with national content and advanced silicon; new research centers will be created in collaboration with the Mexican Optics Association to focus on photovoltaic materials and hybrid technologies, and to lay the foundations for strategic supply network alliances.

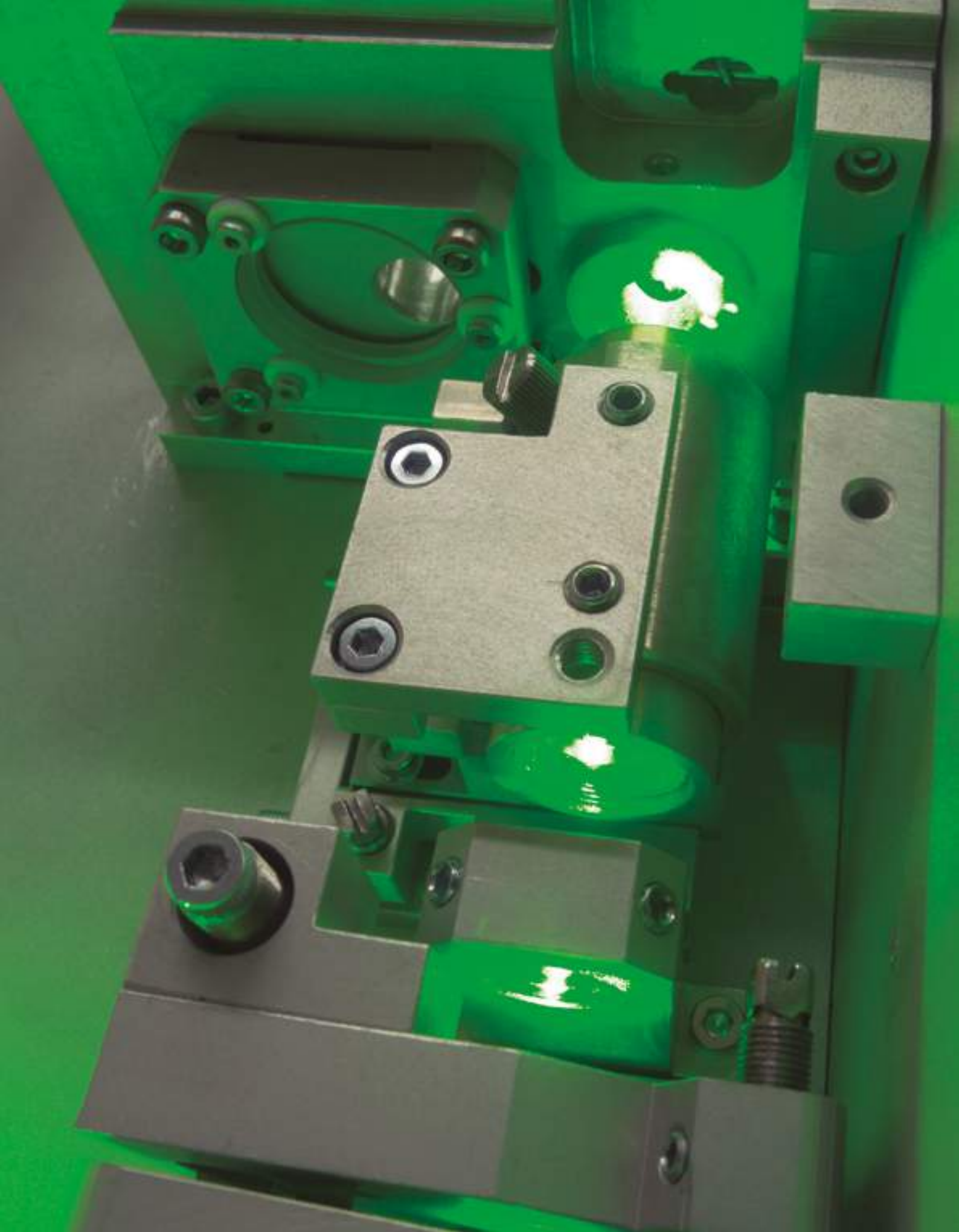
The third milestone seeks to reinforce another of the main national photonics industry areas: connectivity, by expanding the country's optical fiber capacity. An urban connectivity project will be designed to satisfy the constant telecommunication demands, allowing to increase network penetration for civilian, governmental, and corporate users. Thus, it will be possible to articulate regional and national collaboration initiatives with other countries for knowledge transfer through the abovementioned Mexican Photonics Cluster.

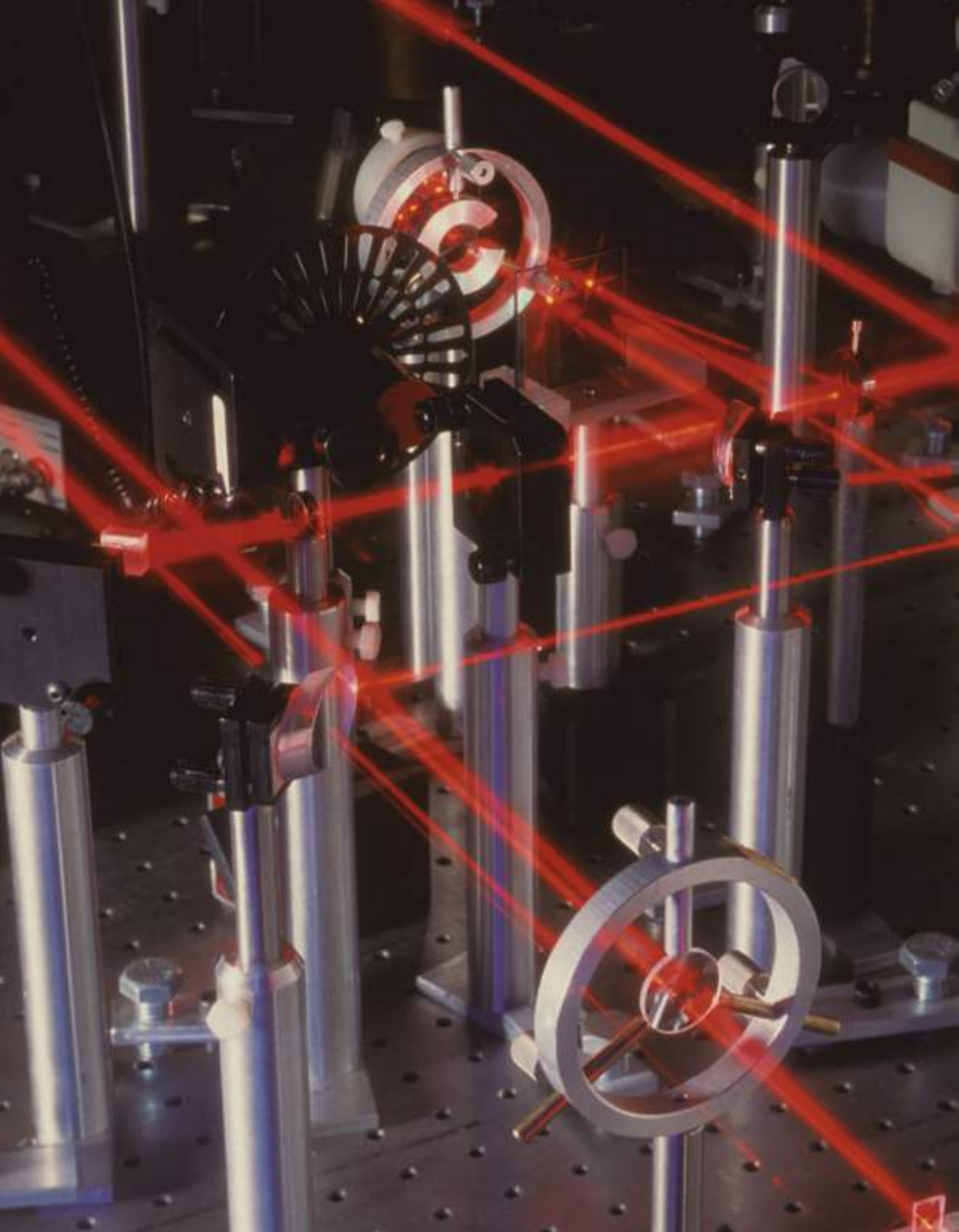
Lastly, the roadmap proposes designing and producing 220 manometer photonic sensors and developing an ultra-high power Petawatt laser. The Mexican Photonics Initiative will promote synergies between industry, government, academia, and civil society, to help to acknowledge optics and photonics as key technologies for Mexico's consolidation as one of the main world economies, and a leader in Latin America.

Other Mexico's advantages are its market size and manufacturing technological race, which make of Mexico a key partner for investment in Latin America. The country must play to its strengths, namely the quality of its researchers, the national talent in innovation and design, the demographic bonus, its infrastructure, and so forth.

It is worth mentioning that once a solid industry integrates into the sector, the ripple effect will multiply Mexico's market value in the very short term. The country will gain even more international recognition in research and regional leadership, due to its own technological contributions and its high value participations (specialized inputs, and advanced technological and design applications). Cooperation with other domestic agents will help explore new opportunities for the Mexican Photonic Initiative and integrate it into the international landscape, which will result in the country's regional leadership and participation in international projects with other leading countries.

The international community is very interested in collaborating with Mexico's photonics initiative, and is willing to provide capital (human, economic, and scientific) for roadmap projects in collaboration with the Mexican Optics Association.





2.2.2 ACTIONS AND PROGRAMS TO PROMOTE INNOVATION

During this government, special attention has been given to public policies seeking to exploit new technologies and the development of a healthy ecosystem for the innovation, development, and utilization of new technologies, mainly in Mexico's strategic sectors.

Although these public policies focus on social aspects, they are especially important for domestic and foreign companies wishing to invest in or develop a long-term strategy in terms of innovation and development of technological capacities.

Trend	Associated Public Policy
Internet of Things	• PROSOFT
Digitalization	• National Digital Strategy • PROSOFT
Automation 3D Printing	• Regional Clusters Policy (indirectly)
Energy efficiency	• Energy reform • Legal framework for the co-generation projects in industrial companies

In the following pages, we explain the most important strategic actions implemented by the Mexican government to boost confidence and foster a favorable environment for i4.0 and the modernization of the Mexican industrial sector.

National Development Plan

The *2013-2018 National Development Plan* (PND) established the "Modern and Proximate Government" (Gobierno Cercano y Moderno) strategy, which outlined the following action lines:

- Guaranteeing access to information and personal data protection; encouraging accountability.
- Establishing a *National Digital Strategy* to encourage the adoption and development of information and communication technologies; and fostering an efficient government to insert Mexico into the Knowledge Society.
- Consolidating a government that is productive and efficient in achieving its goals, through adequate resource management, merit recognition, the use of best practices, and the implementation of automated administration systems.

Another related strategy is the one known as "Reactivating an Economic Advancement Policy Focused on Increasing Mexican Dynamic and Traditional Sectors' Productivity, Balanced Per Region and Sector."[17] For the latter, the following action lines were defined:

- Implementing an economic advancement policy contemplating the design and development of regional and sectorial agendas, and development of innovative human capital; fostering high value strategic sectors; developing and promoting value chains in strategic sectors; and supporting technological development and innovation.
- Articulating, from a cross-sectional regional and/or sectorial point of view, the design, execution and follow-up of projects oriented to strengthen the country's competitiveness by the three levels of government, the private initiatives, and other parts of civil society.

National Digital Strategy

This PND's approach resulted in a document entitled *National Digital Strategy*. "The fundamental purpose of the Strategy is to create a Digital Mexico, where ICT are adopted and used to maximize their economic, social, and political impact to improve people's quality of life."[18] This document, which sets out the public policy around issue, and was promoted by the National Administration, includes five goals; the second goal is key as it deals with the country's economic processes.

One of the initiatives that resulted from this strategy and that has the largest potential on the Mexican productive sector, has been the development of a *Sectorial Agenda for the Development of Information Technologies in Mexico 2014-2024*.

NATIONAL DIGITAL STRATEGY GOALS

1	Governmental transformation	Build a new relation between government and civil society, focused on citizens' experiences as users of public services, through the adoption of ICT by the National Administration.
2	Digital economy	Develop a digital economy ecosystem that will contribute to Mexico's prosperity by incorporating ICT to economic processes to stimulate productivity, economic growth, and the creation of formal employment.
3	Top-quality education	Integrate ICT to the educational process, both in educational management and in teaching-learning processes, as well as to teacher training, and culture and art dissemination and preservation to allow the population to successfully insert itself into the Information and Knowledge Society.
4	Effective and universal health	Create a comprehensive digital health policy using ICT, with two priorities: expand coverage, effective access, and quality of health services; and make the country's existing health infrastructure and resources more efficient.
5	Citizen security	Use ICT to prevent social violence, articulating citizenship and authorities' efforts towards common goals to promote security, and to prevent and mitigate damages caused by natural disasters.

Source: Federal Government (2013), National Digital Strategy.

[17] In Spanish: "Reactivar una política de fomento económico enfocada en incrementar la productividad de los sectores dinámicos y tradicionales de la economía mexicana, de manera regional y sectorialmente equilibrada."
[18] From the document "Estrategia Nacional Digital", Verbatim. Can be consulted electronically on: http://cdn.mexicodigital.gob.mx/EstrategiaDigital.pdf

PROSOFT

The Program for the Development of Software Industry and Innovation (PROSOFT 3.0) stems from the Sectorial Agenda for the Development of Information Technologies in Mexico. It specifically focuses on:

I. Training human capital specialized in information technologies and innovation in strategic sectors.
II. Generating applied research, technological development and innovation in strategic sectors.
III. Funding businesses in strategic sectors so that they can develop and adopt innovation and information technologies.
IV. Generating infrastructure for the development and adoption of innovation and information technologies.
V. Generating and disseminating IT and innovation knowledge through studies and events.

PROSOFT 3.0 STRATEGIES AND GOALS

Digital market	Stimulate the market by linking the different economic sectors' demand with the IT products and services of quality in Mexico
Corporate innovation	Enhance the IT sector's corporate culture in terms of innovation and specialization.
Talent and excellence	Stimulate the development and identification of competencies, skills and staff for the IT sector.
Globalization	Promote business leads overseas and attracting investment for the IT sector
Funding	Increase options and possibilities of access to financial resources for IT businesses.
Smart regionalization	Encourage smart specialization to consolidate competitive clusters based in specific niches of high value IT.
Legal certainty	Facilitate the development of a legal framework to encourage IT production and adoption.
Governance	Integrate and articulate the actions and agents of the IT ecosystem.

Source: Ministry of Economy, Sectorial Agenda for the Development of Information Technologies in Mexico: 2014-2024.

PROSOFT 3.0 is an effort by the Ministry of Economy that has provided dozens of businesses in the country with the necessary funds to develop an ecosystem of innovation. In 2016 alone, this program granted 850 million pesos to support different businesses and projects[19].

In the document *Amendment of the Operating Rules for the Program for the Development of Software Industry (PROSOFT) and Innovation for the fiscal year 2017* (Modificación de las Reglas de Operación del Programa para el Desarrollo de la Industria de Software (PROSOFT) y la Innovación para el ejercicio fiscal 2017) reads, verbatim:

"This convergence between the physical and digital is known as the i4.0 model. Thus, the Ministry of Economy, through its Program for the Development of Software Industry (PROSOFT) and Innovation, promotes the development of projects in that industry to strengthen the innovation culture, and the adoption of IT, supporting projects that strengthen a broad scope of industrial sectors. The i4.0 model consists of the capability to incorporate information technology to productive processes in a profitable way. This is the Program's end goal, and, in order to achieve it, it is necessary to have the necessary technical and organizational skills. This program will support projects geared to creating innovation ecosystems that have positive externalities and impact on multiple industries, are self-financed and can be replicated by different industrial clusters in the country."[20]

The abovementioned is a significant sample of the Federal Government's approach to the development of public policies and is part of the guarantee offered by the country to foreign businesses that wish to create an innovative ecosystem that meets contemporary challenges.

Policy for Industrial Promotion

The Ministry of Economy has developed an industrial policy dividing the different industrial branches into three groups: mature, dynamic, and emerging. Following this classification, each group's specific needs are addressed:

	SECTORS	POLICIES
Mature	• Metal-mechanic • Textile-clothing and leather-footwear • Wood and furniture • Iron and steel • Food and beverages	Foster productivity
Dynamic	• Automotive & auto parts • Aerospace • Electric • Electronics • Chemicals	Increase competitiveness
Emerging	• Biotechnology • Pharmaceutical • IT • Creative industries • Medical devices	Attract and foster emerging sectors

Source: Ministry of Economy.

[19] The list of the 2016's beneficiaries can be consulted on: https://prosoft.economia.gob.mx/doc/beneficiarios%202016.pdf
[18] Read the full document on: https://prosoft.economia.gob.mx/ro2017/MODIFICACION%20ROP%202017.pdf

In this way, the Ministry of Economy established an Industrial Policy matrix, shown below:

INDUSTRIAL POLICY MATRIX

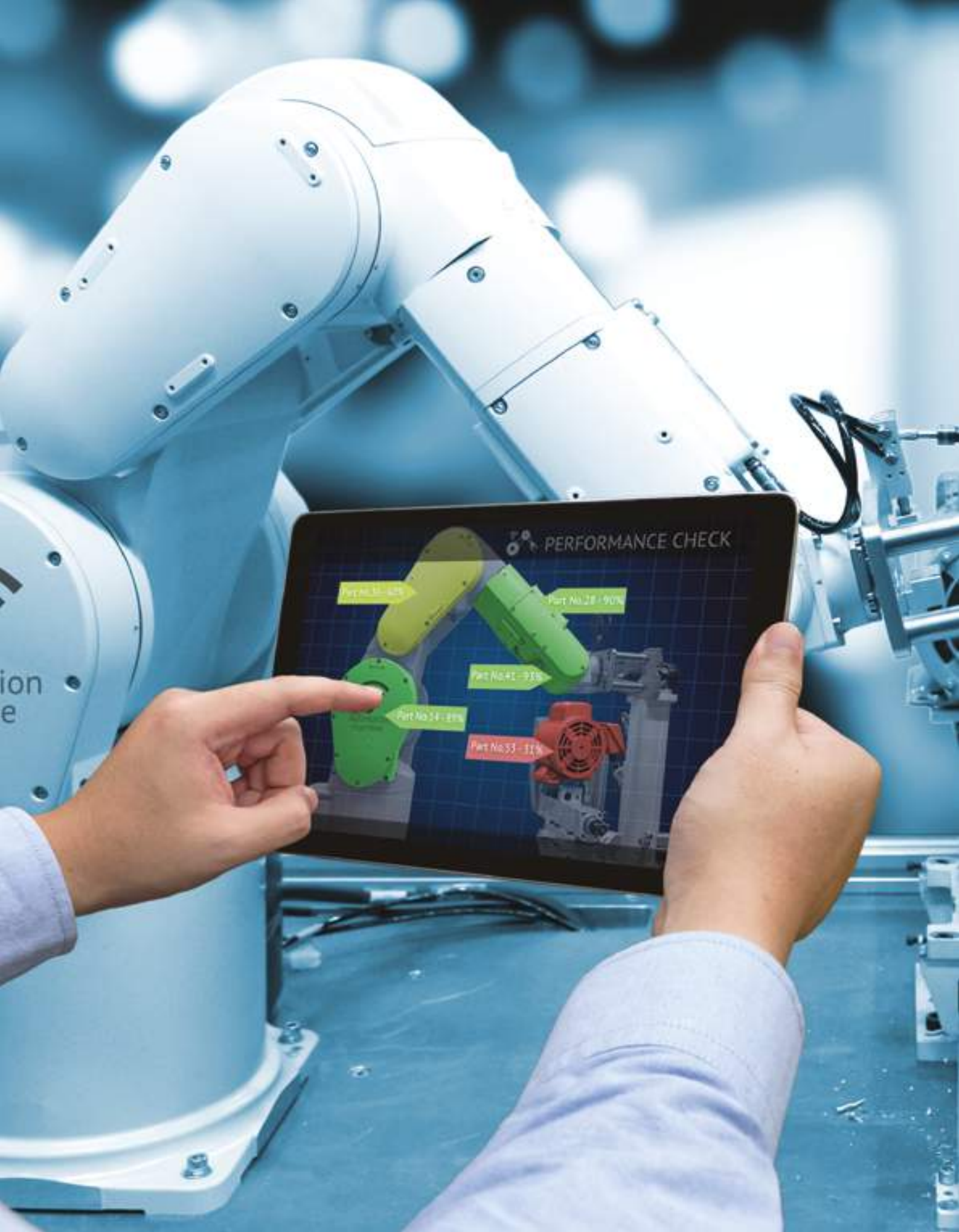
	GUIDELINES	STRATEGIES PER SECTOR		
		MATURE	DYNAMIC	EMERGING
SUPPLIERS DEVELOPMENT	• Proactive and oriented • Join efforts with the industry • Resources security • Results follow up	• Incorporate suppliers to value chains through tractor companies • Increase the production value added	Increase the technological and productive capacity of suppliers to sell to more world class producers	• Create a minimum base of suppliers • Link with the productive sector
REGIONAL CLUSTERS	Consolidate clusters, existing or in formation	• Link them with dynamic sectors. • Create manufacturing regions with a defined purpose and uniform standards	• Automotive: Nuevo León, Guanajuato, Chihuahua, Estado de México, Aguascalientes & Puebla • Aeronautical: Baja California, Chihuahua, Querétaro, Nuevo León & Sonora • Electronic: Baja California, Jalisco & Chihuahua	Program for intersectoral linkage
INNOVATION	Linking with the productive sector	• Articulate broad scope capacities development projects. • Support industrial reconversion and investment in physical, human and technological capital.	Create networks of high level innovation and development centres	• Encourage high level human capital training • National initiative to foster the Digital Market

Source: Ministry of Economy.

In the case of the automotive industry, the public policies identified and lead by the Ministry of Economy in matters of innovation and human capital, are as follows:

- Identify and disseminate the technological and human capacities of the automotive industry available in academia, industry, and government; and create a network of researchers, engineering centers, and laboratories.
- Support projects that invest in technological research, design, and development of the automotive industry.

It is worth mentioning the regional cluster policy that has eased access to i4.0 technologies mainly to businesses with little investment capacity. For example, in the case of the Nuevo León Automotive Cluster (CLAUT), the different committees offer specific services at different stages of the value chain; such as design, 3D printers for prototypes, access to specific innovative knowledge, links with academia and research centers, and solution development, among others.


PERFORMANCE CHECK

2.3 FINAL REMARKS

Industrial innovation trends are setting the path for the development of the different sectors and markets. The Fourth Industrial Revolution phenomenon must be understood as a giant step towards new productive models and consumption patterns. As such, it is the open door of the digital transformation innovation-based systems, networks, and interactions.

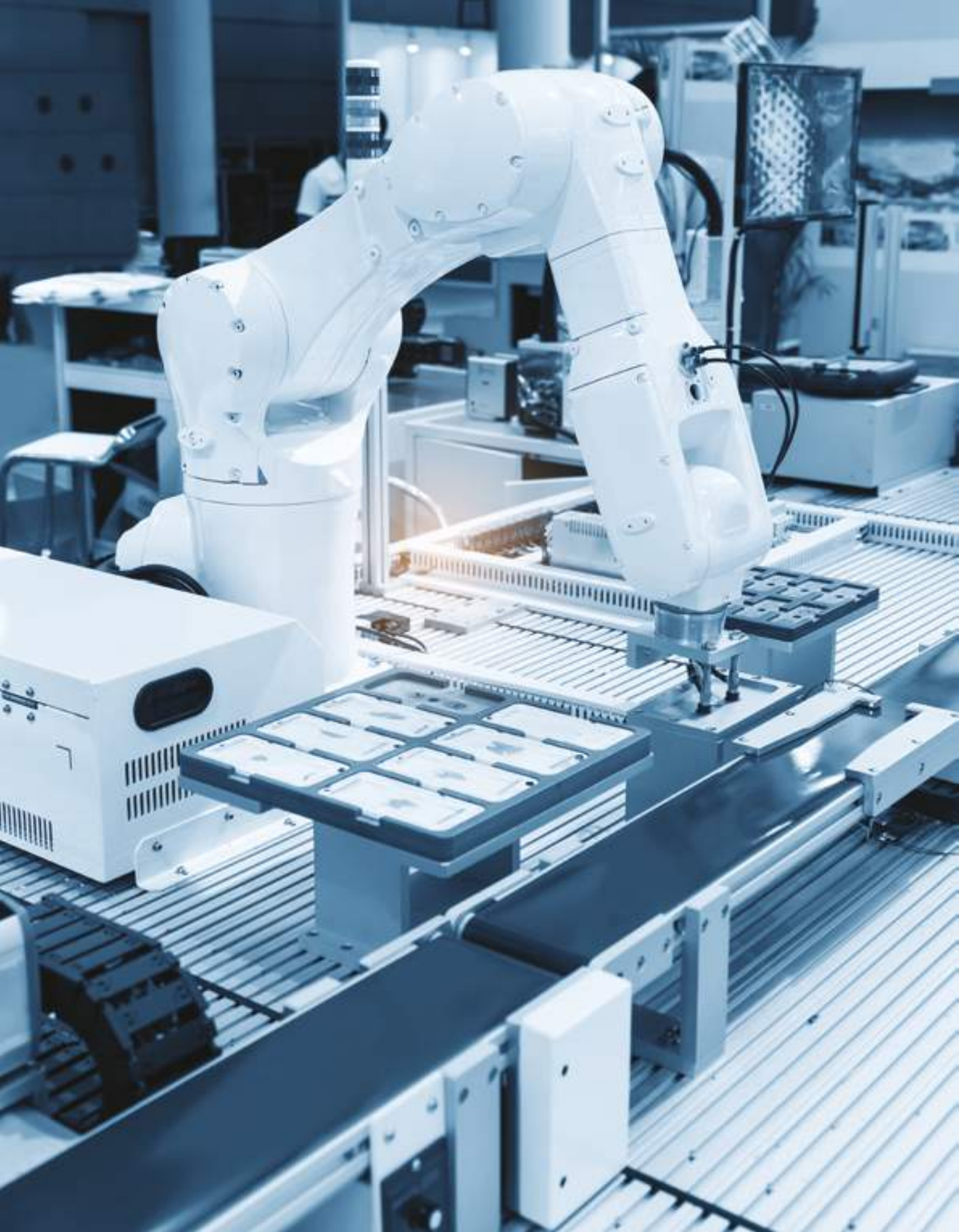
This awareness leads us to conclude that falling behind in terms of technological updates (in industries, services and daily life) could cost institutions, businesses or nations greatly leave them out of the new digital era, resulting in years of economic, and to some extent, political, delay. Integrative participation in the application of these trends entails becoming an active party in new models of global value chains.

Mexican manufacturing industries are sufficiently advanced and mature to implement i4.0 solutions and build strategic alliances with the leaders in industrial innovation, enhancing advanced manufacturing processes from concept and design to after-care services, tailored to each client's needs.

The strategies and intentions included here have been the result of the main concerns expressed by government, industrial and academic players, who push for collaborative actions towards international cooperation, in order to attract more foreign companies experienced in the use of disruptive technologies, that will help to develop local supply networks. These strategic outlines also frame the vision for an innovative Mexico, with the necessary strengths and capacities to offer attractive business opportunities to its allies.

As a result, the close interaction between companies of different sectors in competitive clusters will enhance the efficiency of key processes and the production chain, and will bolster joint investment to produce industrial technologies, as well as technological transfer to consolidate productive capacities within the i4.0 framework; hence positioning Mexico as a testing hub with continuous improvement in this new ecosystem, and granting it the well-deserved title of "***a partner with future***."

CONCLUSIONS



CONCLUSIONS

This book has been an integrated effort to portray Mexico as a strong ally to innovate. As shown in part one, the country has a series of strengths in terms of its developed infrastructure, its broad network of free trade agreements, its state-of-the-art R&D capacities, its increasing highly-qualified talent and its mature economic sectors (automotive, aerospace, medical devices, electronic, metal-mechanic and information technologies). By discussing and understanding the present context of Mexico´s industrial outlook, it is possible to appreciate the country's strategies and vision the country aims to accomplish.

Furthermore, the interaction of the triple helix has created favorable dynamics for innovation based on project collaboration, materialized in competitiveness clusters. These key clusters constitute the corner stone of an ecosystem that encourages innovation-related activities in Mexico. Thus, businesses established in the country can find all the necessary means to advance R&D and implementation of Industry 4.0 technologies for their own benefit and for their entire supply chain, which is becoming more integrated than ever before.

Part two showcased Mexico's actions and projects that translate the country's vision as an ally of global tech-leaders in the development and implementation of new technologies. While the Fourth Industrial Revolution digitally transforms numerous productive processes in key sectors based on two principles: connectivity and integration, Mexico is offering a fertile soil with a long-term vision for new investments opportunities and business projects.

In this regard, one of the key objectives of this book has been to encourage the reader to have a thorough understanding of Mexico's capacities and strategies as a platform for innovation. One in which it is possible to imagine and, most importantly, achieve new businesses related to research, design, implementation and manufacturing of new technologies. Henceforth, ProMéxico will actively assist in the realization of new investments projects through its network of international offices by providing key information and guidance. Today, Mexico is ready to become your ally for innovation.

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