CRAFTING THE FUTURE

A ROADMAP FOR INDUSTRY 4.0 IN MEXICO

SE SECRETARÍA DE ECONOMÍA
ESTADOS UNIDOS MEXICANOS
PROSOFT 3.0
PROMÉXICO Trade and Investment
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Amiti Mejores empresas de TI para México
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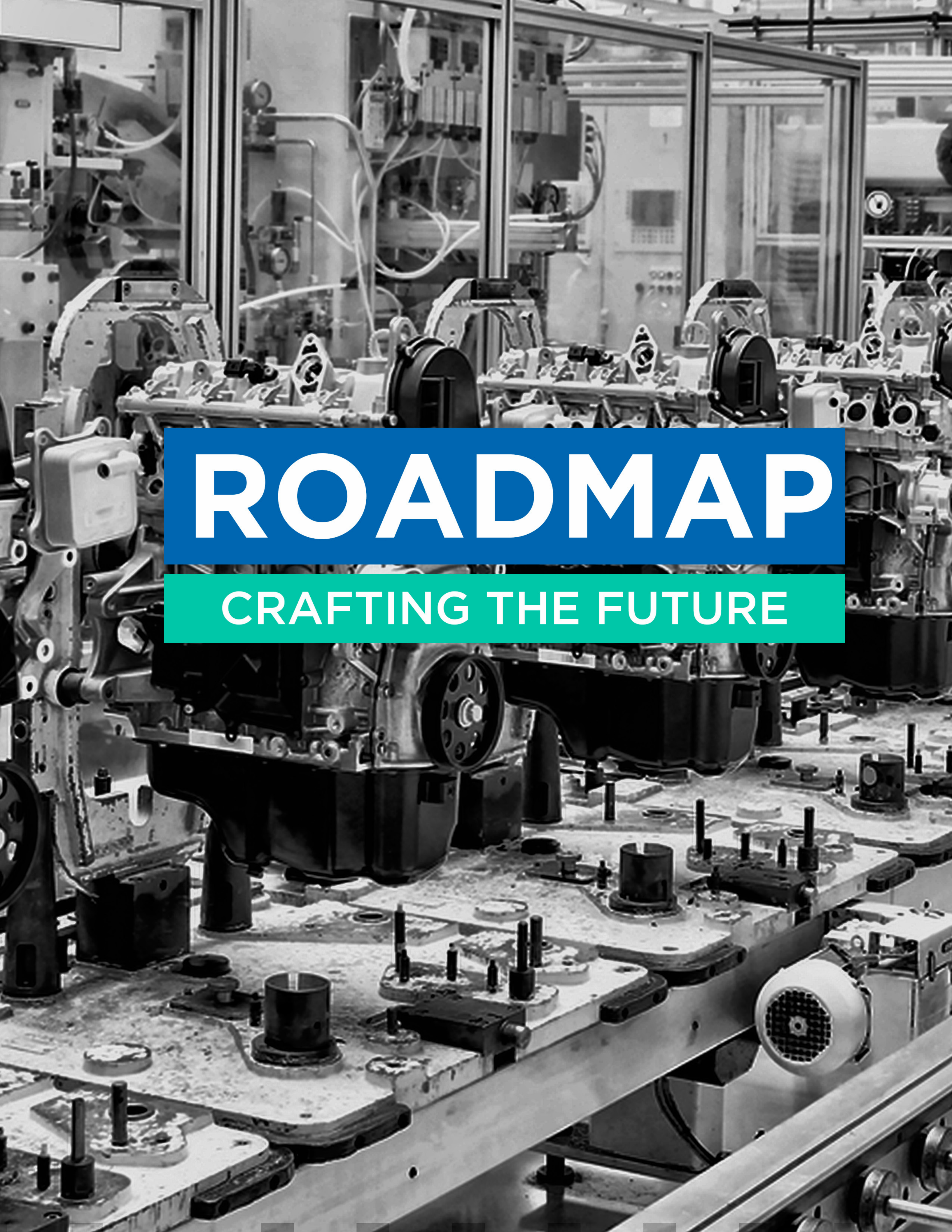

ROADMAP

CRAFTING THE FUTURE

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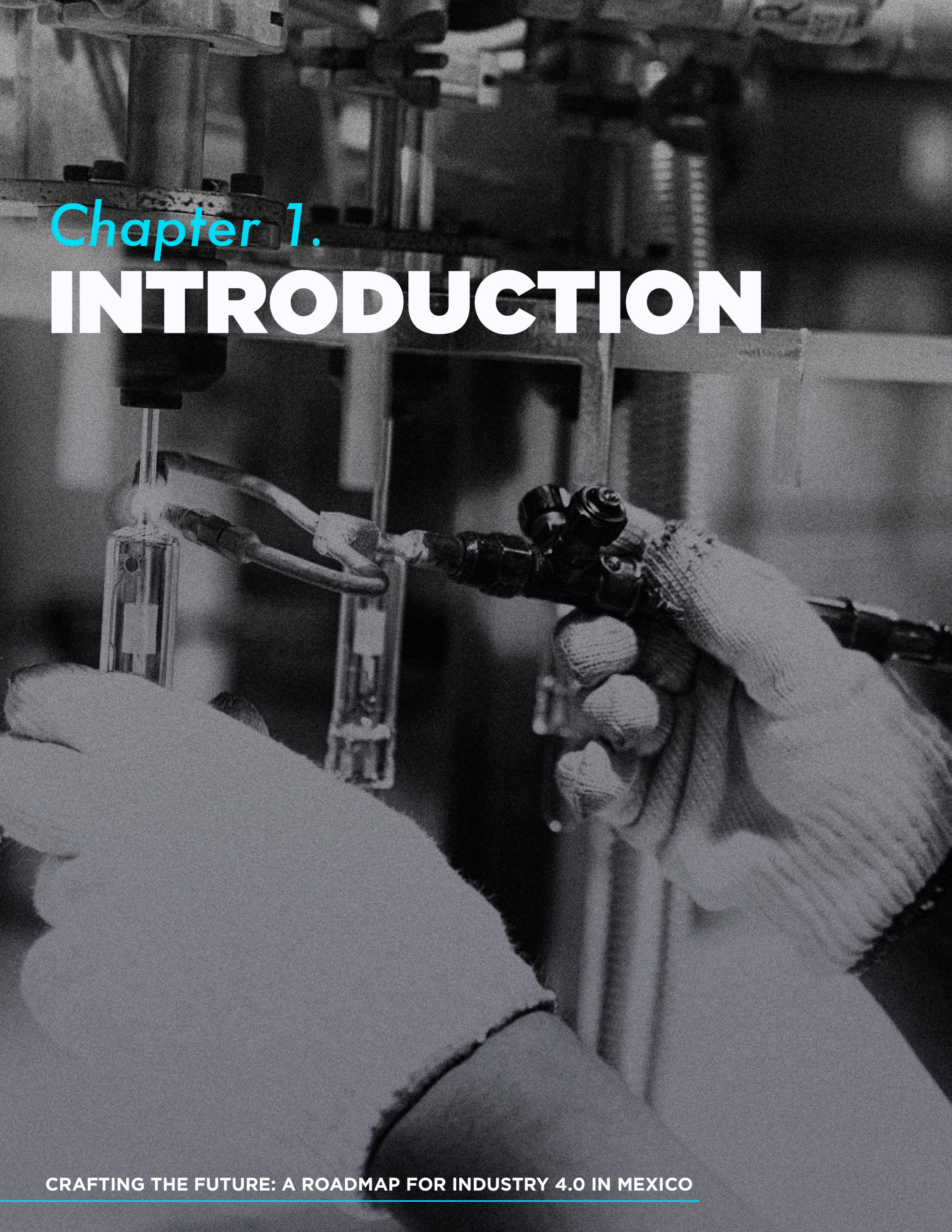
INTRODUCTION



I. INTROD

1.1. *INDUSTRY 4.0* CONCEPT AND GENERAL TERMS

The crosscutting impact of information and communication technologies, especially the Internet of Things (IoT) in various industrial sectors translates itself into a phenomenon that specialists have defined it as the fourth industrial revolution: Industry 4.0, or I4.0.

Its purpose is to revolutionize the industry through "smart factories" that will allow greater flexibility in production needs, efficient allocation of resources, and integration of processes; from equipment monitoring to final delivery, through the use of technologies such as integration of Cyber-Physical Systems (CPS), IoT and IOS, and the real time interaction between machinery, software, and individuals.

The concept of Industry 4.0 is a reality in consolidation, and will become a new milestone in industrial development, which will undoubtedly set significant changes in the way of production and trade during the upcoming years.

This revolution is supported by the development of systems that transfer the ubiquitous advantages of the Internet and information systems towards physical systems; the core of the revolution is the interaction of digital systems with physical production systems.

UCTION

While this interaction already existed since the incorporation of PLCs and other microprocessors to manufacturing plants, I4.0 refers to the massive instrumentation of production systems, and to the holistic approach in the analysis and management of global value chains. This trend is mainly supported by the confirmation of the Moore's Law and its impact in the exponential reduction of costs and miniaturization of processors and sensors that will lead a network of sensors and processors (Planetary Skin[1]) that, for 2020, will have 50,000 million connected devices (most of them in manufacturing systems).

According to Siegfried Dais, leader of this initiative in Germany, "it is highly likely that the world of production will become more and more networked until everything is interlinked with everything else", through the engine of the Internet of Things, strongly developing supply networks, the complexity of production, and the supply and demand market. Network and processes will no longer be connected to a single factory, but through Industry 4.0, the limits of individual factories will be deleted with the interconnection of multiple factories or regions.

Such networks shall require the development of operating systems focused on the optimization of highly-complex productive ecosystems that grant greater adaptability and efficiency: Operating Systems with Manufacturing Clusters.

Industry 4.0 will provide great flexibility and robustness, along with the highest quality standards in engineering, management, manufacturing, operations, and logistics processes. It will detonate dynamic value chains, optimized in real time and with an automatize organization, which will consider various variables such as costs, availability, and use of resources and market demand. This change of paradigm represents a window of opportunity for Mexico with considerable potential, since it would allow the convergence of two distinctly competitive strategic sectors in the country: Manufacturing and Information and Communication Technologies.

1 Evans, Dave. The Internet of Things: how the next evolution of internet is changing everything, 2011.

1.2. *INDUSTRY I4.0* AND MEXICO

It is widely known that Mexico is a world-class Manufacturing Hub, exporting more than one billion dollars per day. Fifty per cent of these exports are manufactured products, from this a large portion are highly sophisticated technologies. In fact, more than **80% of high tech exports in Latin America are produced in Mexico,** with the country exporting even more sophisticated goods than Canada[1].

International trade agreements, along with the correlation between the Mexican Peso and the US Dollar, plus the experience gathered from electronics and automotive industries, have created a highly competitive zone for the development of a manufacturing export industry. This situation, in the past few decades, has attracted a great number of companies interested in Mexico as an export platform.

In addition, these companies want to take advantage of the qualified engineers and labor force, international trade agreements, and Mexico's adscription to a dollar zone. European and Asian companies are among the most appealed by Mexico's competitive advantages, particularly when the United States is the final market.

Even though this economic development model has allowed Mexico to keep its export volume, it is insufficient to maintain the country's competitive position. The model deficiencies limits the ability to generate an associated value chain, and a supplier base with an endogenous innovation capacity and an intellectual property level aimed to increase the value added in produced goods, and with it, the country's strategic position within the global innovation market. As a result, a two-speed economy has been created, even different international consulting firms have mentioned it: multinational, highly competitive and productive companies,and Mexican SMEs with low productivity. As a fact, the system is composed with: large companies concerned with evolving towards fourth generation production models (I4.0), and a subsisting SME community stalled in first or second generation productive models.

However, in light of this situation, it is very important to understand Mexico's geostrategic position, and take advantage of its potential to the benefit of Mexican companies and its innovation systems. Seeing us as a world-class economic and manufacturing leader at the level we are viewed by Japanese, Europeans, and Americans; and act according to such expectations.

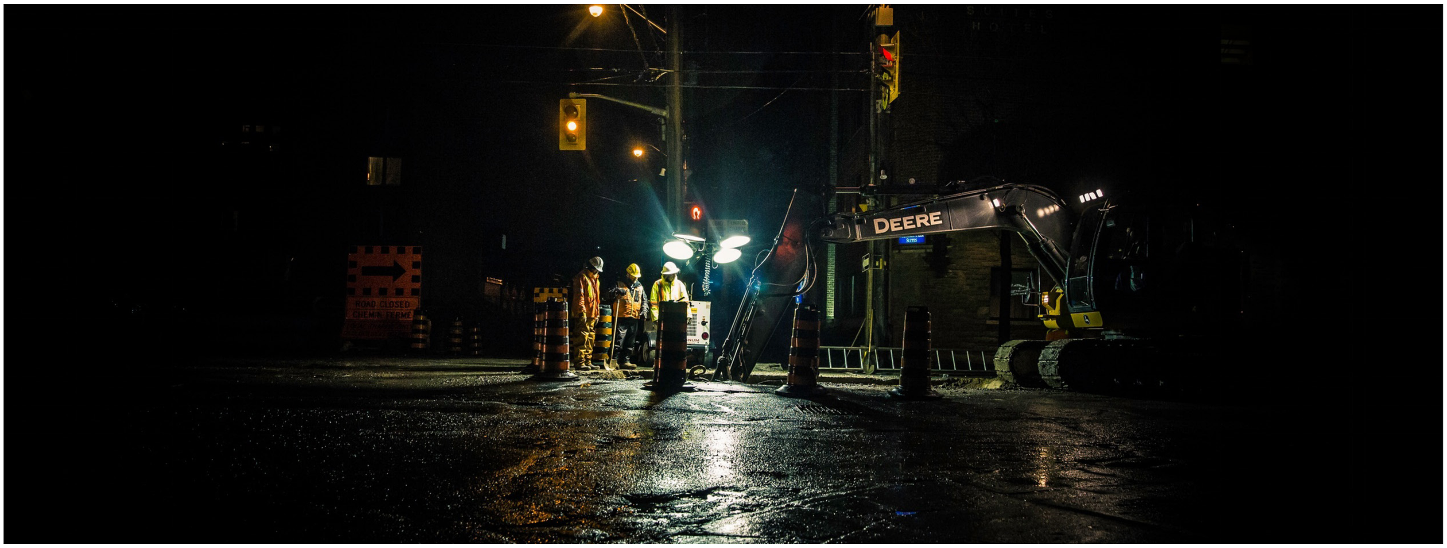
Cost competitiveness advantage should be leveraged with a long-term vision of the future and as a source of opportunities for developing capacities beyond costs, which largely depend on cheap labor costs. It is necessary to focus on innovation capabilities, the development of Mexican brands (local champions), the supply chain, the productivity, and all other relevant factors that provide long-term advantages.

Advanced manufacturing industry is a highly different from the prevously conceived manufacturing paradigm we are used to conceive: a filthy, dangerous, and obscure plant. It would only take a visit to a Mexican automotive or aerospace plant to find out facilities that are the opposite of that notion. We may bump into highly-qualified computer experts and workforce.

Unlike traditional manufacturing facilities, advanced manufacturing does not rely on low-cost labor force and high production volumes; but it is an industry that lapses in skills and creativity to manufacture highly-specific complex products. In addition, it is not composed by an isolated group of companies but a network of engineers, business developers, entrepreneurs, scientists, financial managers, and other highly-experienced professionals that collaborate and bring their creative potential together around innovative solutions for users and customers.

The granular approach, focused on the company as an economic unit, has displayed major limitations when analyzed from a perspective of sustainable economic development throughout the regions. A global optimal development cannot be achieved with the combination of local optimal developments as the systems theory asserts; a group of non-synergic companies does not necessarily produce a successful sustainable development (extreme case: monopolies and monopsonies). A government economic vision demands a more global perspective, with productive ecosystems and regions, where government decisions should be taken with a focus on "corporate acupuncture", activating ecosystem-detonating nodes. An important outcome derivative of an I4.0 vision is precisely a productive ecosystem model that creates value, focused on interconnectivity between smart industrial units.

On the other hand, it is worth highlighting that, although the confluence of the industrial policy supporting the manufacturing and export industry (IMMEX, by it's acronym in Spanish) may be regarded as successful through foreign trade policies – that have achieved to position Mexico as one of the most open countries in terms of global trade, a review over national agregated value is still pending, which progressively gets lost within the international context, and is the true wealth generator. The Ministry of Economy (SE, for its acronym in Spanish) began an Innovative Development Program strategy, in where these topics become the country focus towards an increase in exports value added through the creation of clusters, vertical productive developments (development of suppliers) and internationalization of Mexican companies.



Although this situation is critical, it offers us a large window of opportunity when fully analyzing the limitations of the current industrial policies and understanding them as a step towards a higher scenario.

Even though this situation is critical, it will offers us a large window of opportunity once the limitations on the current industry policies are fully analyzed and there are understand as a step towards a higher level. Externalities produced by a manufacturing industry in constant improvement are particularly important. Mexico manufactures highly-sophisticated technological products at greater levels than the average of OECD countries, and comparable to in Korea and Japan; this has developed generations of skilled production plants directors, operators, engineers, among others, with the potential skills needed to assimilate new technology and the best international practices aimed to create high value added for Mexico.

Talent and access to disruptive technologies, best international practices and a world-class manufacturing industry; the ingredients are here, only the strategy is missing. The purpose of this Roadmap is to present a first approach towards the national value added strategy for the manufacturing industry through the implementation of Industry 4.0 strategies and technologies.

Chapter 2.

4.0 STRATEGIES AROUND THE GLOBE

The purpose of this section is to analyze the industrial policies and plans developed regarding Industry 4.0 around the globe. For such purpose, the selected countries were segmented into two groups: leading countries in technological innovation (usually capital asset developers); and countries specialized in manufacturing services (limited capacities for developing capital assets). The first classification analyzes public policies and practices of countries that have been leaders in technological innovation; it studies the measures implemented to complete the transition process. In the second classification, the countries that were chosen are those ones whose manufacturing sector is vital for the local economy, however, they don't develop technological advances that would position them as a worldwide innovation referents.

2.1. LEADING COUNTRIES IN TECHNOLOGICAL INNOVATION

2.1.1. GERMANY

With the purpose of maintaining itself as one of the leader countries in technological innovation and competitiveness, in 2012 the German government published The New High Tech Strategy Innovations for Germany (HTS), one of the most ambitious projects to ratify their worldwide technological leadership through new innovation policies.

The new government's technological innovation plan is based on 5 cornerstones (see diagram 1)**, wich its purpose is to underpin the leadership of the country in technological innovation.** The first pillar of the HTS strategy, establishes six key improvement areas, those are: digital economy and society; economic and energetic sustainability, along with labor, health, and civil security innovation.

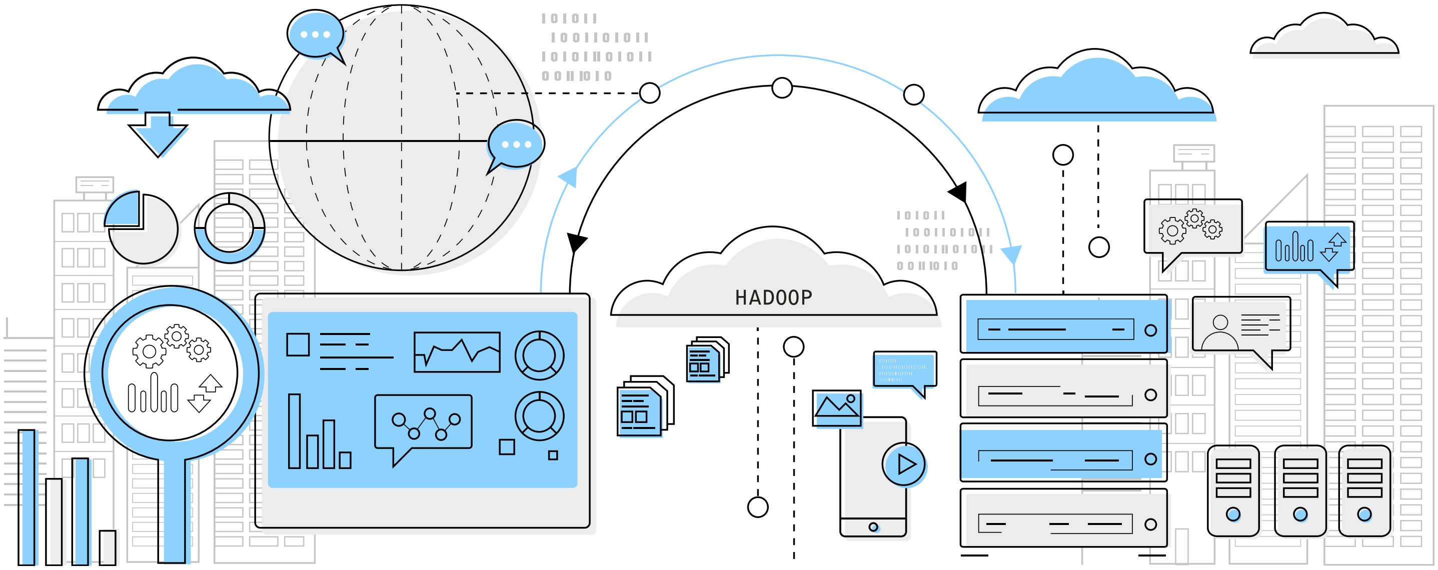
DIAGRAM 1
ELEMENTS FOR INNOVATION POLICY

Source: Own development with information from The New High-Tech Strategy Innovations for Germany.

The first area, digital economy and society, displays the government's interest in the opportunities offered by the digital technologies, to integrate them into the administrative processes, industry, society and political involvement (See Table 2). Knowing that the policy needs to be consolidated and the citizens need to benefit from it, the government developed the Digital Agenda 2014-2017.

POLICY	DESCRIPTION
Industry 4.0	Implementation of the model to underpin the country as a leading supplier of technologies and a production hub.
Smart services	The use of smart devices has transformed the production processes and services. Due to the potential that these devices have, the government is planning to support companies so they can maintain control of their value chains and production processes.
Smart data	With the execution of the Smart Data program, the government expects to reduce problems found in medium and small companies with the use of applications such as Big Data. It is forecasted that the problems will be resolved through the promotion and testing programs of innovation services with the use of Big Data Technologies.
Cloud computing	The Trusted Cloud technological program pretends to boost among medium small companies, cloud-based solutions that are innovative and secure; this, with the purpose of allowing them to access new technologies to which previously only big companies could access.
Digital Networking	After considering secure communication networks, and the interoperability between various technologies as key pieces of intelligent applications and innovation services, the government is working to expand high-performance connectivity networks.
Digital Science	Digital technologies have opened multiple opportunities for science sector, specifically in research and cooperation. Thus, the government has decided to strengthen science-digital information infrastructures, along with ensuring access and use of digital information. For this purpose, the creation of an Infrastructure and Information Council is planned; this will provide recommendations to support science sector.
Digital Education	Since the education system needs to prepare individuals efficiently regarding the use of digital media, as well as on the cognitional requirements demanded by society, the government decided to emphasize the use of digital media in education.
Digital life environments	Digital progress has impacted the daily life of individuals, creating new challenges and opportunities in the family sphere. Likewise, gaps have been created between individuals that follow this process and those who do not. Now the families have the necessity of being supported in leveraging the opportunities that come with the diffusion of new technologies.

Source: The New High-Tech Strategy: Innovations for Germany.



Currently, many German companies are already offerring services and solutions for organizations that are willing to implement this model. One of this is Siemens, which provides solutions through its Digital Factory division. Siemens offers its customers a hardware and software product portfolio that allows the integration of data in development, production, and supply stages; the name for this solution is Digital Enterprise. Another relevant example worth mentioning is Bosch, which through the use of its Bosch Software Innovation division provides alternatives for companies that would like to automate their production. This segment offers a wide range of products and services, such as Bosch IoT Suite, which offers various solutions, related to cloud services.

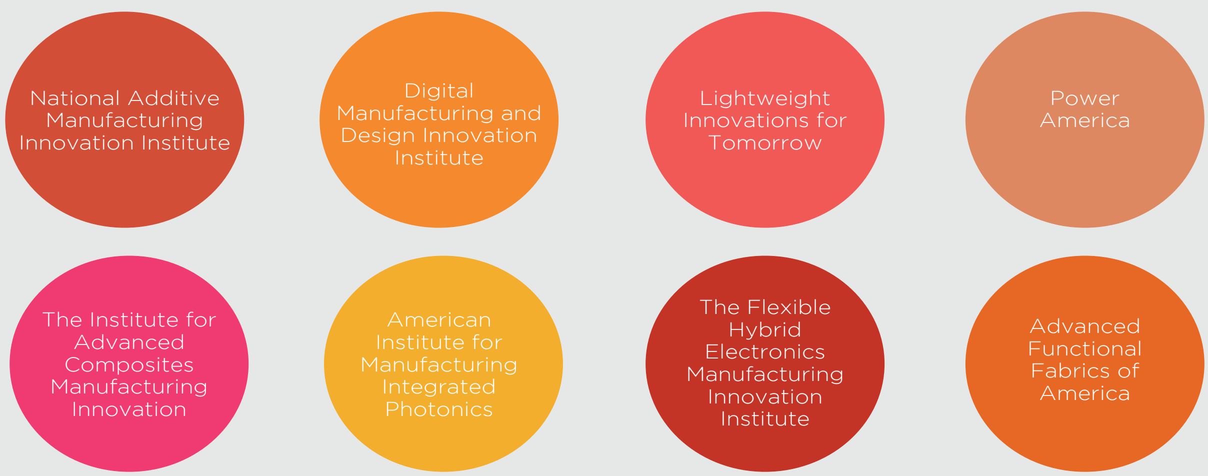
2.1.2.- UNITED STATES OF AMERICA

In 2011, President Barack Obama announced the Advanced Manufacturing Partnership program as part of the recommendations made to the President's Council of Advisors on Science and Technology (PCAST). This strategy would be led by the president, the CEO of the Dow Chemical Company (Andrew Liveris), and the President of the Massachusetts Institute of Technology (Susan Hockfield).

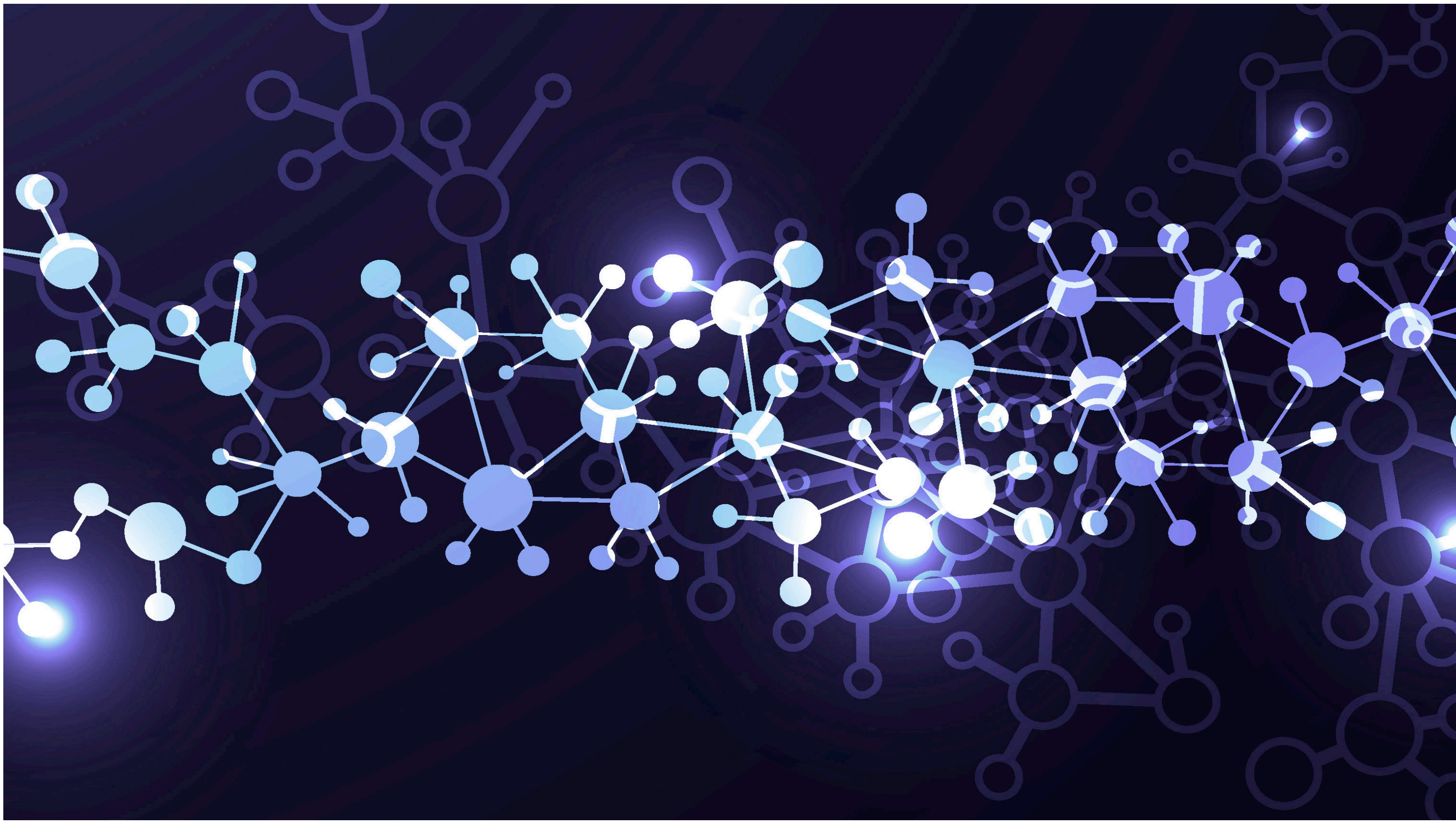
Subsequently, by presidential decree, the **Nationwide Network for Manufacturing Innovation (NNMI) created as a public-private association that promotes the use of processes and technologies in advanced manufacturing.** The NNMI is funded by the National Institute of Standards and Technology, and is ope- rated through NIST's Advanced Manufacturing National Program Office (AMNPO). The AMNPO operates in partnership with the Department of Defense (DoD), the Department of Energy (DoE); the National Aeronautics and Space Administration (NASA); the National Science Foundation (NSF); the Department of Education (DoEducation), as well as the US Department of Agriculture (USDA).

The NNMI consists of various institutes specialized in manufacturing innovation (see diagram 2). Furthermore, they provide infrastructure to small manufacturing companies and startups, so they can use new technologies, speed up the technology transfer process, and facilitate the workers' training process. Other institutes are in the formation process, with a planned total of up to 45.

INSTITUTES FOR BOOSTING TECHNOLOGICAL INNOVATION IN THE UNITED STATES

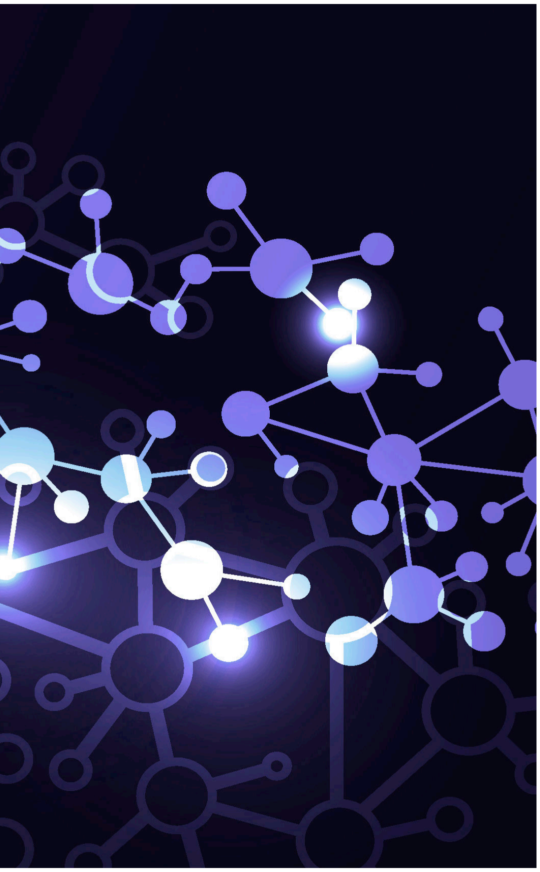


According to the Manufacturing.gov website, in addition to the NNMI, there are other initiatives that promote advanced manufacturing innovation and increase competitiveness in the United States. The digital manufacturing strategy focuses on the development of a marketplace of applications and on the full integration of manufacturing supply chains in the country.



2.1.3. CANADA

The Canadian government has design a project named *Digital Canada*, which consists of 150 initiatives focused on 5 pillars: Connection, Protection and Cybersecurity; Economic opportunities; Digital government; and Digital Canadian Content. The economic development area of the project has **allocated 200 million dollars in investment to support entrepreneurs in the application of information and communication technologies for business**. Additionally, the Venture Capital Action Plan is a strategy to increase private investment in innovating businesses. **In terms of human capital, the government initiative focuses on supporting 3000 interns every year for SME's (Small and Medium-sized Enterprises) in science, technology, engineering and mathematics.**



2.1.4. EUROPEAN UNION

The main policies related to Industry 4.0 in Europe are the ones proposed by the European Commission in 2012, which mentions that European SMEs should be backed up in terms of value added and advanced manufacturing. The initiative called Reindustrializing Europe highlights the potential of advance manufacturing to regenerate the industrial base of Europe, under the Horizon 2020, which is the innovation and research program that leads efforts of member countries in these topics. The investment will be of 80 billion euros between 2014-2020. One of the main objectives of this initiative is to increase the value added of manufactured goods in the European Union by 20% for 2020.

In terms of employment, the Grand Coalition for Digital Jobs program was developed as the main strategy of the EU; its main goal is to strengthen digital skills on workers within the European Union, and to make digital education more attractive and aligned with the industry needs. Organizations in Europe for Industry 4.0 initiatives has been structure mainly under the Public-Private Associations model. One example is the European Factories of the Future Association, which focuses on collaborative, advanced, and smart manufacturing, centered on humans and consumers. For this initiative has a budget of € 1.5 billion. Innovation for Manufacturing SMEs is another association designed to support SMEs in the manufacturing sector specialized in cloud computing, robotics, and simulation; the budget for this initiative was of 77 million euros.

2.2. COUNTRIES SPECIALIZED IN MANUFACTURING SERVICES

2.2.1. CZECH REPUBLIC

In September 2015, the Ministry of Industry and Trade (MIT) presented the ***Průmysl 4.0*** initiative, which identifies the vision and technological pre-requirements of the country; obligations related to applied research and standardization, as well as the impact of this policy in the labor market, the educational system, and the regulatory framework. For this purpose, the following visions were considered:

SYSTEM PERSPECTIVE THROUGH THREE VISIONS

VISION	DESCRIPTION
Horizontal Subsystems Integration	Considers all of the production stages, from the reception of the production order, security in shipment, and customer services. Termination of the product's life cycle.
Vertical Subsystems Integration	Gives preference to automation processes (which react in milliseconds) from the production department to the company's planning of resources (considering changes over time).
Computational vision for integrating all the engineering processes	Participation in the design, development, implementation, testing, and verification stages of the product, as well as its life cycle.

Source: Own development with information from the Czech National Initiative Průmysl 4.0

The MITr, folowwing the next action steps, coordinates part of the development and concept of this work plan:

a) The creation of specialized teams for the development of the work plan (October 2015).

b) The work plan will included the following aspects (February 2016).

- Support plan for investment in Industry 4.0 security solutions and standardization.
- Implementation of the support plan for OP PIK[1] research, along with other relevant programs.
- Human resources development program.
- Changes in the academic program of initial and continuous education.
- Law initiative and cyber-security plan for Industry 4.0.
- Plan for the development and use of I4.0 technologies in the energy sector.
- Plan for the creation of Smart Cities.
- Development of financial instruments and tax incentives to promote the execution of I4.0 projects.

c) Submission of the work plan to the Czech Republic government (March 2016).

2.2.2. TURKEY

The Digital Conversation Association of Turkey has the following objectives and goals: the digital transformation of the national economy to contribute to the country'sdevelopment; to support digital conversion; to organize conferences, events, and seminars; to provide information for supporting the creation of qualified labor force; to integrate industry players on conversations regarding digital topics; etc. The structure of the Turkish economy is mainly composed by the manufacturing industry, wich contributes with 24.3% of the GDP; transportation, storage, and communication, represents 14.9%; and wholesales and retail, accounts for 12.7%[1]. Turkey is one of the main manufacturing countries for the European countries, being Germanu the main destination of its manufacturing exports. Reason why the transformation of this industry in Turkey will be highly influenced by German companies.

2.2.3. SOUTH AFRICA

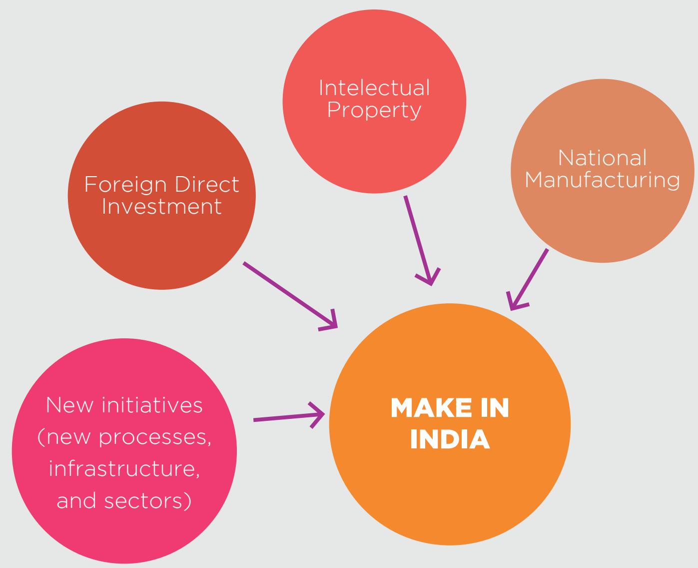
The country's GDP in 2015 was approximately US $ 317billions. The GDP distribution reveals that South Africa is a country focused on services (67.4% for it's GDP), industry (30.3%), and agriculture (2.4%). South Africa has the potential for the developing of an Industry 4.0, mainly in the extracting industries, such as mining; which requires the implementation of technologies that connects sensors and allowing them to process the vast amount of information generated. This will allow the sector to remain competitive in a complex global environment. It is important to mention that the country has already presented its national strategy to implement the I4.0 model.

2.2.4. INDIA

The country has implemented different economic and industrial policies aimed to direct the country on the path to adopt the Industry 4.0. An example is is *Make in India*, a measure taken to strengthen and improve competitiveness in the manufacturing sector. In September 2014, the government presented an initiative with the purpose of positioning the Asian country as one of the main hubs of global manufacturing and design.

Likewise, various projects have been proposed to improve and expand industrial parks, and to increase the country's industrialization and to make manufacturing the main economic driver in the country.

POLICIES TO BE IMPLEMENTED



Source: *Make in India*

LIVE PROJECTS

PROJECTD	ESCRIPTION
Construction, extension and improvement of Industrial corridors	Increase manufacturing industry's share in the GDP to 25% in 2020.
Creation of Smart Cities	It is expected to build up 100 Smart Cities which will held the labor force to boost the industry
National Industrial Corridor Development Authority (NICDA)	Creation of an authority with the power to integrate all the industrial corridors.

Source: Own development with information from *Make in India*.

An important action taken by the government for resolving digital lags is Digital India, a strategy coordinated by the Department of Information Technologies and Electronics. This strategy indicates the relevance of the National Information Infrastructure (NII), that promotes the integration of the network and cloud infrastructure to provide a faster connectivity (as well as the cloud platform) for different government departments.

2.2.5. SPAIN

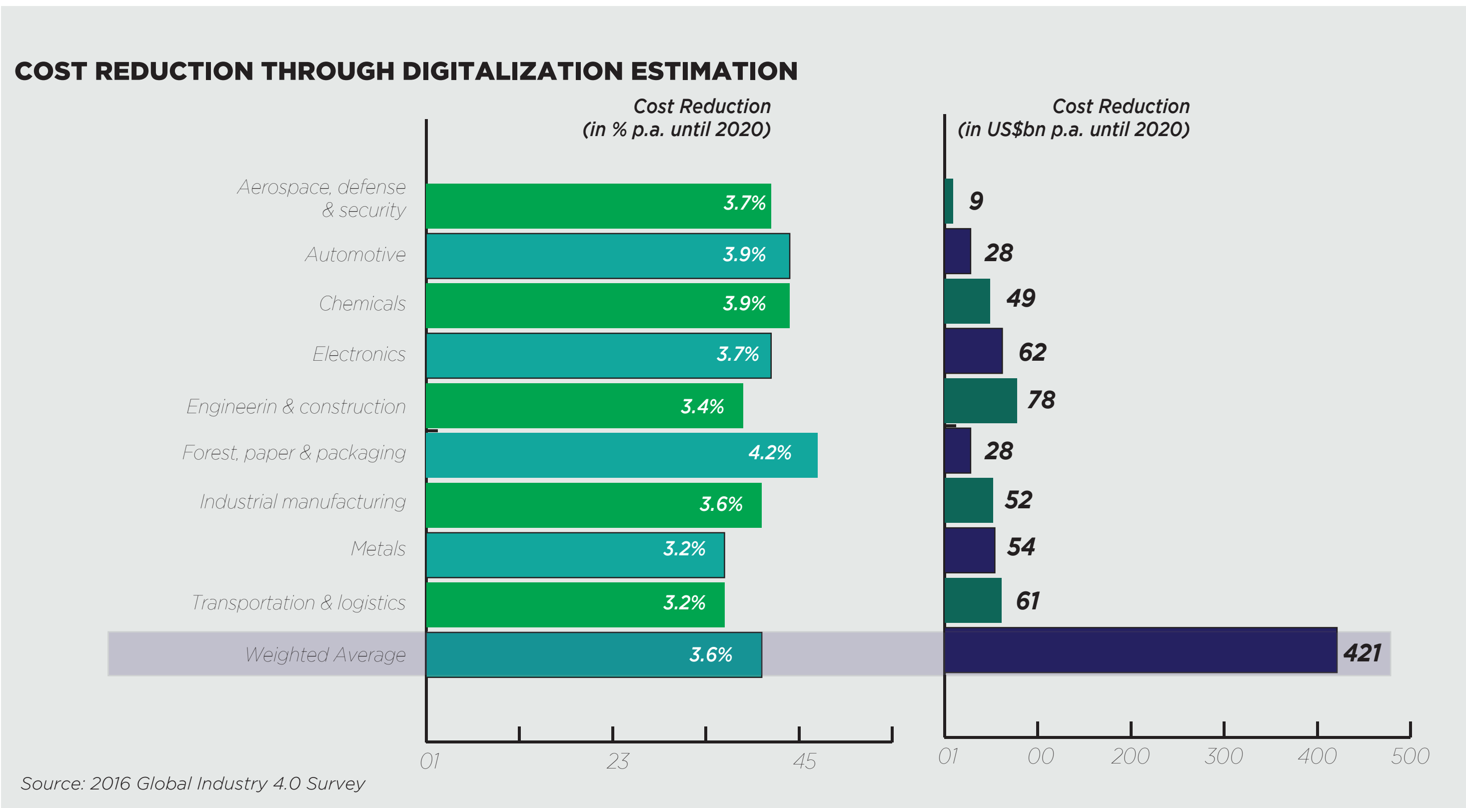
In Spain, the Industry 4.0 topic has been addressed by the Federal Government through the Ministry of Industry, Energy, and Tourism, under the name *Industria Conectada* 4.0. In regards to the Agenda for Strengthening the Industrial Sector in Spain (2013), the objectives are:to develop the Digital Agenda for Spain (2013), these are the following objectives: developing the digital economy for growth, competitiveness, and internationalization of the Spanish company; to promote promoting the deployment of networks and services to guarantee digital connectivity; to encourage the inclusion and digital literacy, as well as the development of new ICT professionals, among others.

The Industria Conectada 4.0 (Connected Industry 4.0) has the goal of increasing competitiveness among Spanish companies on the global market; through the following strategic lines of action and strategic areas: 1.- To guarantee knowledge and technological development of I4.0 skills. 2.- To promote multidisciplinary collaboration. 3.- To promote the development of a group of enablers. 4.- To promote the I4.0 implementation. The strategic industries in Spain, due to their contribution to added value and occupation are the food and beverages industry, manufacturing of metals and motor vehicles and components,

Chapter 3.

TRENDS

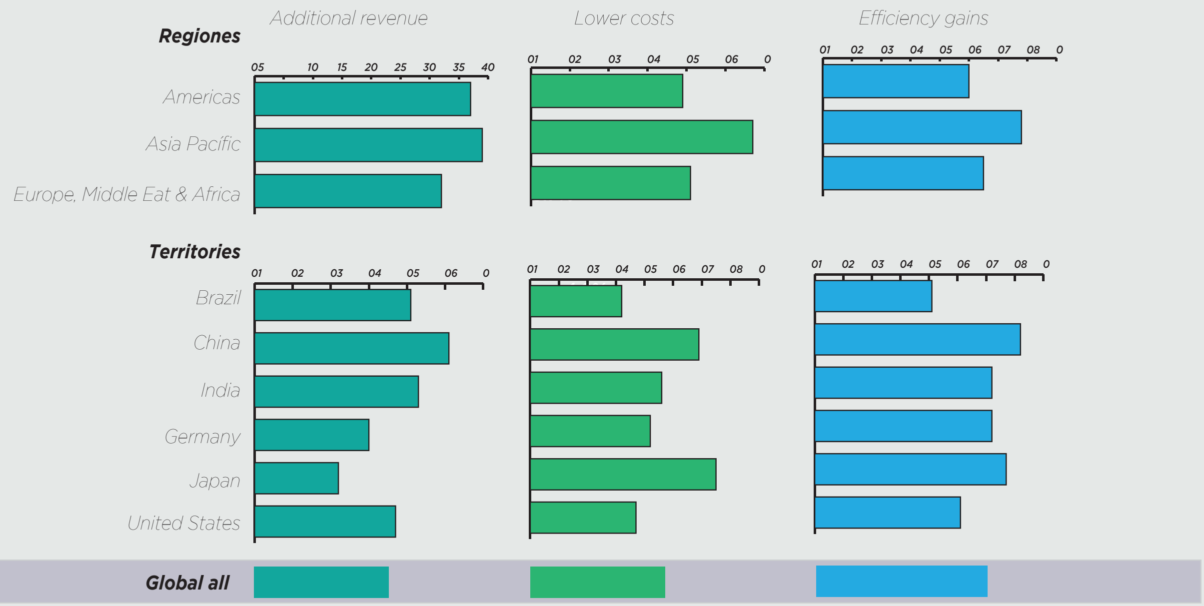
One of the benefits of digitalization of manufacturing is cost reduction by eliminating inefficient processes. **In this sense, according to the 2016 Global Industry 4.0 Survey[1] developed by PwC, different interviewees admitted that, through digitalization, they expect to reduce costs, which would represent savings of US $ 421 millions in the next 5 years** (Illustration 1).



Regarding profits derived from digitalization, PwC estimates around US $ 43 billions. However, the survey states that developed countries will benefit mostly in the short term. For emerging nations, it is expected that the benefits of this process will take a couple of years to be reflected. Significant areas of opportunity will remain.

1 The document can be read in the following link: http://www.pwc.com/gx/en/industries/industries-4.0/landing-page/industry-4.0-building-your-digital-enterprise-april-2016.pdf

EXPECTED PROFIT THROUGH DIGITALIZATION



Source: 2016 Global Industry 4.0 Survey

3.1. E-COMMERCE

This new business model has also allowed consumers access to a wider range of products. Likewise, it has allowed large multinationals to operate in different countries without the need of physical offices. Such is the case of Amazon, Mercado Libre, and Alibaba, which are consolidated in product sale through the digital market. According to the annual reports of these companies, their revenues from sales have presented a steady growth in the past few years (Table 1). In the specific case of Amazon, an increase between 17% and 28% in sales is expected for the first quarter of 2016, compared with the same period of 2015 [2]

2 Amazon 2016, annual report.

E-COMMERCE SPECIALIZED COMPANY SALES

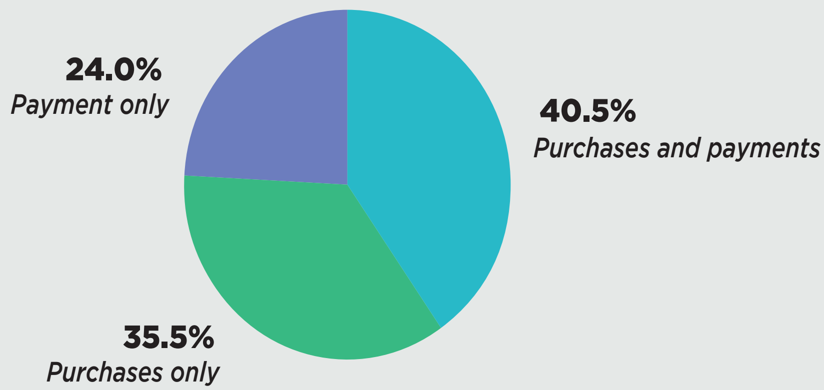
COMPANY	2013	2014	2014
*Amazon**	60,903	70,080	79,268
Mercado Libre	473	556	652
Alibaba	5,614	8,520	12,129

Source: Companies' annual report
Figures in million of dollars
**Amazon's figures refers only to product sale.*

In Mexico, e-commerce is an opportunity niche that has presented a steady growth. According to the National Survey of Availability and Use of Information Technologies at Homes (ENDUTIH, by its acronym in Spanish), the e-commerce market has strengthened. As of 2015, data indicate that there were 7.9 million Internet users that purchased or made payments via Internet.

It is necessary to reap the benefits from online platforms that enable innovative and collaborative forms of production and consumption, including sharing activities, peer to peer; and improve the welfare of consumers and encourage investment and competition.

USERS THAT COMPLETED TRANSACTIONS THROUGH INTERNET IN MEXICO, 2015

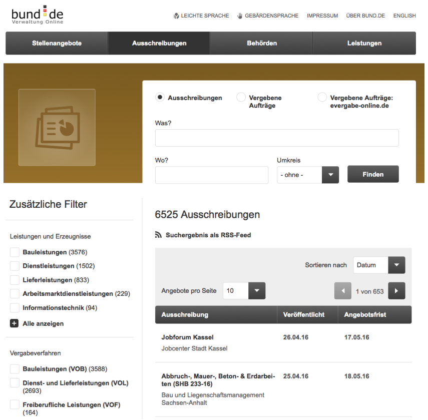


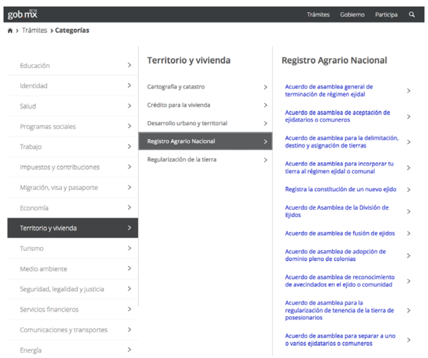
Source: ENDUTIH.

3.2. E-GOVERNMENT

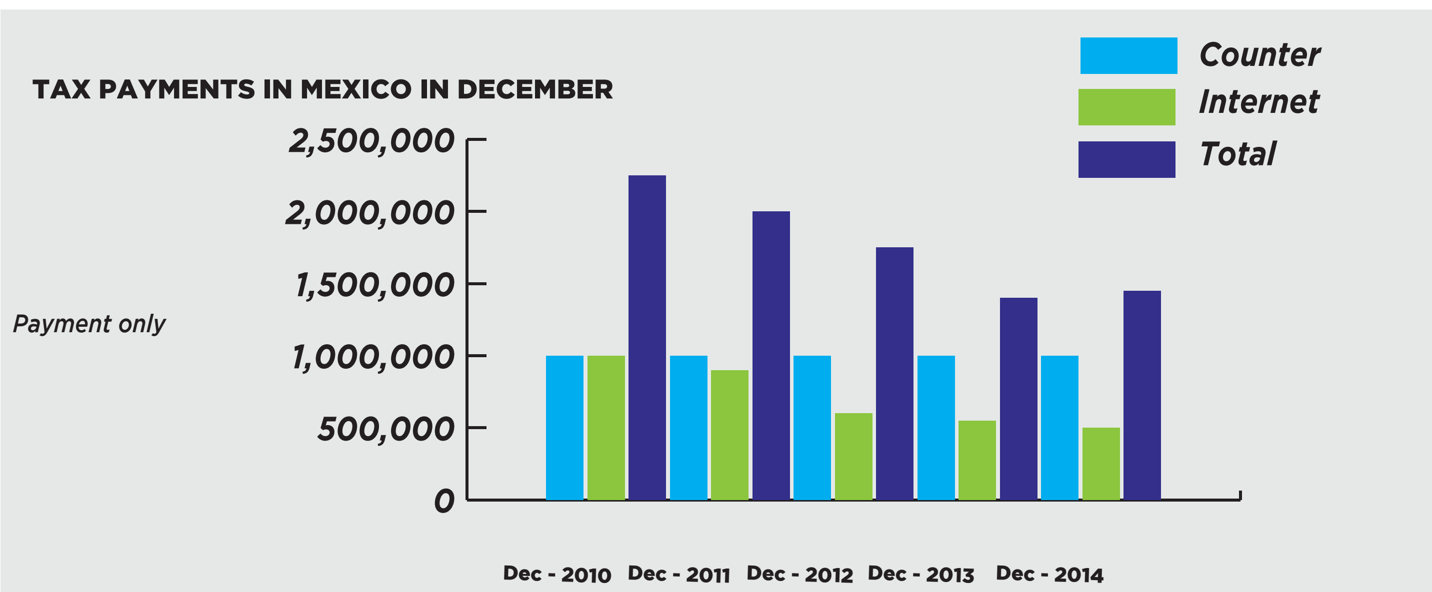
Like companies, governments of each country must create innovative ways to translate digital innovation into social and economic development by the means of on-line platforms and environments that support and creates innovation ecosystems, investment, and collaboration.

This new approach of government-citizen interaction has been positively accepted around the world. Developed countries recorded a higher use of these platforms, according to figures by TechCast Global, around 30% of government operations are completed online. Also, TechCast Global forecasts that the value of e-government services will reach a value of US $ 57 billions; likewise, for 2017, 30% of all public services will be done online.

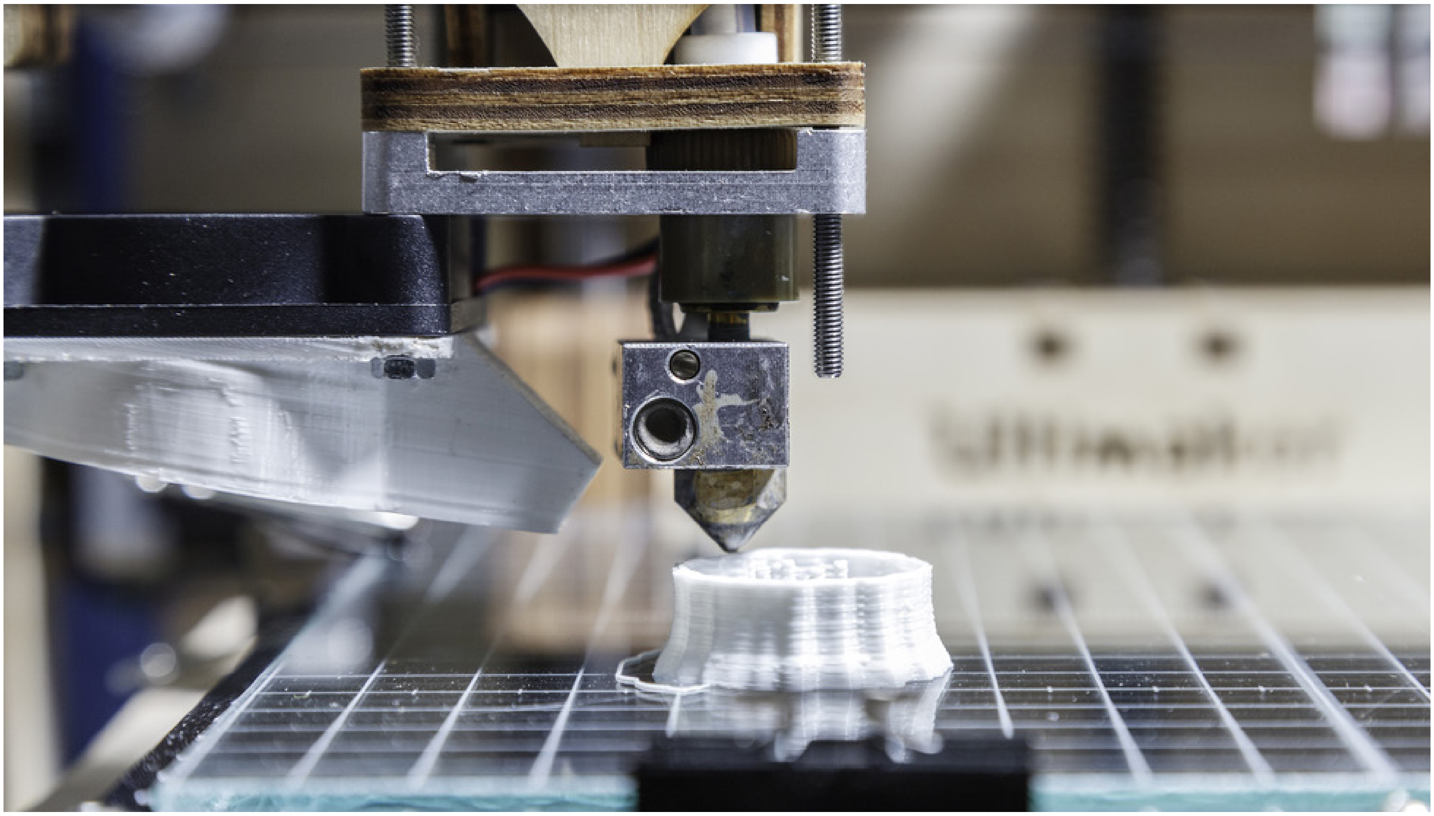




In Mexico, the number of tax payments recorded in December 2015 by the Tax Administration Service (SAT, by its acronym in Spanish) was 1.745 million. Out of this, 40.2% were done online, while 59.8% were made on the counter. In the case of Internet payments, December 2015 displayed the greatest number of tax statements and payments in the past 3 years.



Source: SAT



3.3. 3D PRINTING

With the development of 3D printing, the concept of specialized manufacturing was revolutionized. Through these technologies, individuals can have access to a wider variety of products to satisfy their needs. Those products can be manufactured with tailor made technical specifications, allowing the production of unique goods and reducing production and delivery times. TechCast Global estimates that the market value of 3D printing (considering services, systems, and materials) in 2020 will reach US $ 8.4 billions, with a Compound Annual Rate Growth (CAGR) of 23%. Furthermore, the industries expected to make an intensive use of this technology are: processed foods; heavy industries, and the naval industry; to mention a few.

Currently in our country, innovation and design of this technology is limited, since there are only a few companies that had developed 3D printing technologies. Additionally, the diffusion of the economic and technical benefits of this new technology is limited due to an low understanding of its real capacity. Among the Mexican companies that manufacture these types of equipment are:

MEXICAN COMPANIES IN 3D PRINTING SECTOR

COMPANY	LOCATION
InterLatin (Colibrí 3D)	JALISCO
Latinrep	JALISCO
3D Factory MX	NUEVO LEON
Maker Mex	GUANAJUATO
*Industrias VIWA**	JALISCO

Source: Own research.
*The company developed a machine that combines in a mechanized center, the ability to print metals in 3d.

It is relevant to highlight the creation of the **MADiT (National Laboratory of Additive Manufacturing, 3D Digitalization, and Computed Tomography) located at the National Autonomous University of Mexico (UNAM, by its acronym in Spanish)**, where strategies are design and implemented to develop technologies and processes associated to this trend. In addition, the installed capacity in the additive manufacturing laboratories of the CIATEQ, which include machines for metal processing and high-precision machines; adding to this, the collaboration with the National Nanotechnology Laboratory at the Advanced Materials Research Center(CIMAV, by its acronym in Spanish) is also essential.

3.4. CLOUD COMPUTING

Cloud computing is a trend that consist in the provision of storage services, access, and use of online computer services. This trend can be reflected on three different levels, depending on the service provided: Infrastructure as a Service, Platform as a Service, and Software as a Service. The importance of this technology can be reflected on estimations that indicate that 30% of the digital processing of information will be through the cloud by 2017, with an error margin of 2 years.

It is relevant to highlight that TechCast Global figures indicated that the global cloud market in 2020 would reach a value of US $ 270 billions, growing at 30 % rate per year. Also, 2015 figures[3] indicated that the global market of Software as a Service displayed a market value of US $ 49 billions, and is expected to reach a global value of US $ 67 billions by 2018; with a CAGR of 8.1%[4] Also, according to Wikibon Research, the Platform as a Service in 2014 had a value of US $ 1.7 billions, and it is estimated to reach a value of US $ 68.3 billions in 2026, with a CAGR of 36%. On the other hand, Goldman Sachs estimates that, in 2015, the market value of cloud infrastructure and platforms was US $ 21 billions, and is expected to reach US $ 43 billions by 2018.

3 Source: http://www.forbes.com/sites/louiscolumbus/2015/09/27/roundup-of-cloud-computing-forecasts-and-market-estimates-q3-update-2015/#44d93f276c7a

4 Source: Technology Business Research presentation The Developer's Coup: 2015 Applications Development Demands and Vendor Opportunities.

3.5. ROBOTICS

Robotics is undoubtedly a technology that has catalyzed manufacturing around the world within the past few years, making production faster and cheaper for companies.

In addition, according to the International Federation of Robots, the largest consumption of robots is taking place in Asia, in where 139,300 robots were buy in 2014, an increase of 31% when compared with the previous year. Other relevant regions are Europe, with 45,600 units, and the American continent (including North, Center and South America) with 32,600 units sold in the same period. It is relevant to highlight that, on a country level, the markets with the greatest demand for such equipment are: China, Japan, the United States, the Korean Republic, and Germany, jointly accounts for 70% of the consumption by volume.

In Mexico, investment in flexible manufacturing and robotics grew from 4% to 25% in just ten years[5]. Also, there is a growing interest for prototype robotics, since students from different universities in the country have achieved global recognition in the main international robotics contests like Robogames and First Robotics.

One of the companies with a growing demand of robotics solutions in Mexico is Festo, with business lines offering solutions for manufacturing improvement, and front-end applications.

5 National Survey of Jobs and Technology.

The National Polytechnic Institute (IPN, by its acronym in Spanish), through its Professional Interdisciplinary Unit for Advanced Engineering and Technologies (UPIITA, by its acronym in Spanish), built a laboratory of complex systems in where time series are developed on topics complex networks in different areas of knowledge, including: heart rate variability analysis, thermal machinery stability study, geo-electric signal analysis, among others. It also includes a server dedicated to monitoring geo-electric signals arriving from the Mexican Pacific coast, a server used as a receptor of the seismic alert developed by lab collaborators, and that is continuously communicating in real time with the sensor system installed at the School of Physics and Mathematics of the IPN. This same Institute, through the Center for Investigation and Advance Studies **(CINVESTAV, by its acronym in Spanish), Saltillo Unit, developed the Robotics and Advanced Manufacturing Group, which offers graduate programs in (Masters and PhD's) in Robotics and Advanced Manufacturing Program**. Some of its research lines are: air and submarine robotics, mobile robots, humanoid robots, cooperating robots, and industrial robots; along with strength control, tele-operation, and haptic interface topics[2].

The National Astrophysics, Optics, and Electronics Institute (INAOE, by its acronym in Spanish) has a robotics laboratory with research lines focused on locomotion (water robots, hexapods, and apods), map construction, control and coordination of robots based on decision theories, robot learning, human-robot interaction, and collaborative robots.

2 A set of interfaces aimed to interact with the human being through touch.

3.5.1. MODELING AND SIMULATION

In terms of modeling and simulation, it was found that various entities have developed projects focused on this topic. Among these are: Advanced Technological Center Querétaro (CIATEQ, by its acronym in Spanish), which has the technological capacity to develop precision tools and casts to transform and develop a product. In its prototype laboratory, CIATEQ offers validation of product design aimed to display concepts such as aesthetics, assembly, ergonomics, and functionality of prototype products, allowing the customer (companies) to test its product before starting the manufacturing process. Technologies employed for such purpose are FDM, Vacuum Casting, V-Flash 3D, and SLD 3D.

Likewise, the Intel laboratory located in Guadalajara has participated in 160 global projects in the last 10 years. Some of them are the Code I5 processor used in personal computers and laptops; the Xeon Phi, employed by the fastest supercomputer in the world, the Tianhe-2, among others.

One significant effort for developing endogenous capacities for design in Mexico is the San Miguelense Tech Park, which concentrates several specialization areas such as: design of equipment and computer fluid dynamics; computer simulation; and high tech in petroleum and gas. In addition to these capacities, other relevant projects are, GE-IQ lab, by General Electric, the Ford Design Center, and Volkswagen's Innovation Campus.

3.5.2. SYSTEMS INTEGRATIONS

In this area, Honeywell has established internationally certified research centers and facilities in Mexico. The most important one is the laboratory located in Mexicali, Baja California, which is focused on systems integration, and employs 350 specialists that participate in the design, engineering, and testing of aeronautic components. In Ciudad Juarez, the company established facilities with certifications such as Excellence Center in advanced precision mechanics for commercial and military aircraft, this center is also consider Honeywell's living lab for smart manufacturing.

Additionally, another prominent example is the Center for Engineering and Industrial Development (CIDESI, by its acronym in Spanish), which offers a specialization in Embedded Systems Designs with CAN, SCI, SPI, and I2C communication protocols through the family of Digital Signal Processors (DSP) and microcontrollers from Texas Instruments, Freescale, Renesas, and Microchip.

Finally, the CIATEQ has provided Human-Machine Interfaces (HMI) in terms of software design and development for tests in laboratories and production lines (LabVIEW, LabWindows/CVI, VisualStudio), software design and development for management and monitoring of production lines and processes, tailor-made software (.Net, Java), and Database design and implementation (SQL, MySQL, PosgrateSQL, MongoDB).

3.5. BIG DATA ANALYSIS

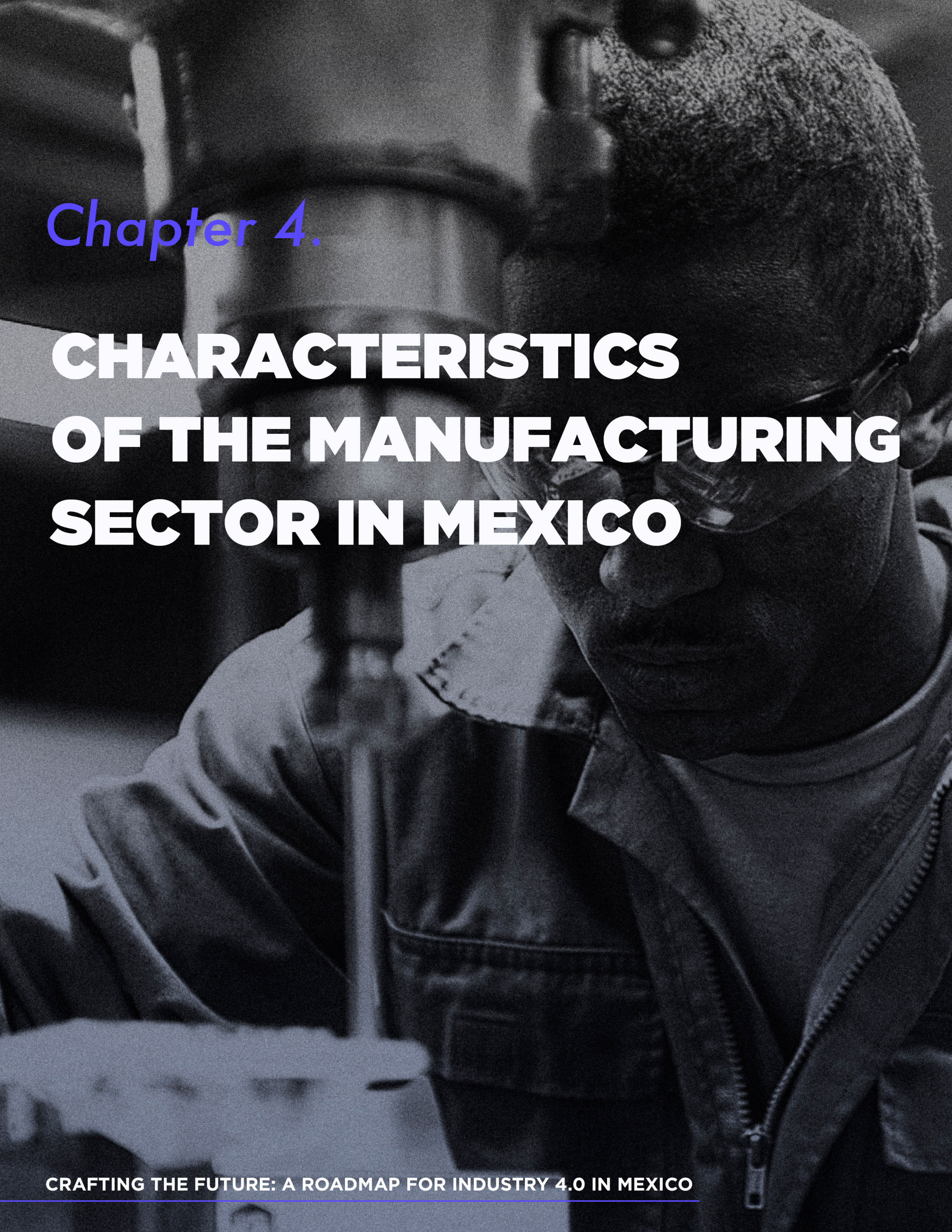
Big Data analysis is currently one of the trends related to Industry 4.0 more demanded on a corporate level, with decision-making being one of the most popular applications among companies. According to a survey made by PwC, almost 73% of the surveyed companies agreed that big data analysis plays a fundamental role in the decision-making process. Likewise, the interviewees indicated that another use for this tool is to control and improve commercial and manufacturing planning, and it is consider to be useful tool for a better customer approach.

In Mexico, there are different public and private entities that developed solutions in Big Data. An example of this is the analytics laboratory (Big Data) of the Center for Research and Innovation in Information and Communication Technologies, headquartered in Mexico City and Aguascalientes. According to this center, this labor integrates different technologies for storage, recovery, processing, analysis, and visualization of large information conglomerates. The lab is recognized as a space for scientific-computer experimentation that integrates big database processing (from different sources), through the application of analytical methods.

The main activity of this center is applied research, which is focus on the development of computer intelligence techniques for reviewing information and its application in topics of national relevance. Some relevant research areas are: evolutionary computing; classification; topological data analysis; opinion mining; search by resemblance; group identification. Among the main projects developed by the lab is the mood map of tweeters in Mexico, which was achieved in collaboration with the National Statistics and Geography Institute (INEGI, by its acronym in Spanish).

Another Big Data initiative is 100 Mexico open data, in which the Federal Government collaborates with The Global Lab of the University of New York to complete the portal. Additionally, it is important to highlight the contribution of the Mathematics Research Center of the National Council for Science and Technology (CONACYT, by its acronym in Spanish) and the Computer Research Center of the IPN in the development of technologies and models associated to big data analysis.

Lastly, IBM has developed a industry-related big data application through its analytics economic unit, which provides its customers with solutions to transform their industries and professions through the use of data. With IBM Analytics, the company states that the users can get patterns and track leading ideas through the interaction and analysis of information. The platform is currently divided into three main areas: industry, technology, and business.



Chapter 4.

CHARACTERISTICS OF THE MANUFACTURING SECTOR IN MEXICO

With the purpose of analyzing the various manufacturing paradigms in strategic sectors in Mexico, **the automotive sector was chosen as the most representative sector of the manufacturing capacities in Mexico**, and considering its high volume production and low mixing of products. **In addition, the aerospace sector is also being analyzed to identify Mexican capacities in the adoption of new technologies and development of new capacities on low volume and high mixing**. Finally, to complement the analysis, the chemical sector will be included due to the relevance of the energy reform, and the challenges it represents in the continuous production paradigm.

4.1. ANALYSIS OF THE AUTOMOTIVE INDUSTRY IN MEXICO

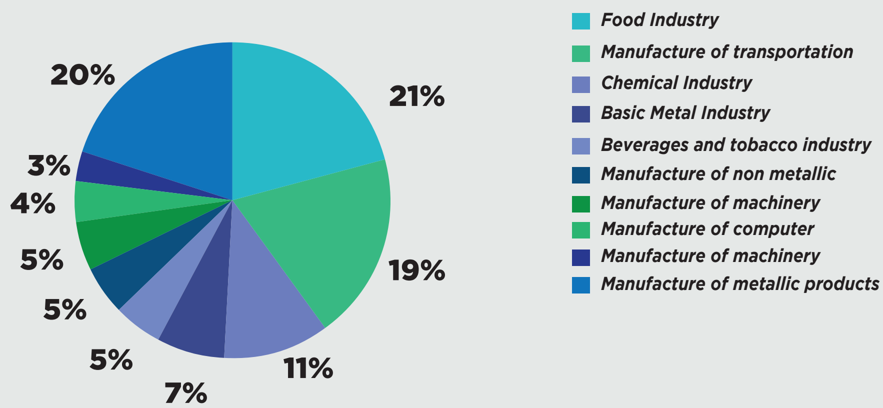
4.1.1. GROSS DOMESTIC PRODUCT AND OCCUPATION

Among the most representative subsectors that led the manufacturing industry in Mexico during 2015 were: food manufacturing; transportation equipment manufacturing; the chemical industry; and basic fabricated metal product manufacturing. In the specific case of transportation equipment, the most important segment is the automotive industry[1], accounting for 92.2% of the subsector's GDP, and 17.7% of the entire manufacturing industry.

In terms of employment, the automotive industry accounted for 715,608 direct jobs; this represents 1.4% of the total country's employment, and 20.5% of the occupation in the manufacturing sector in 2015.

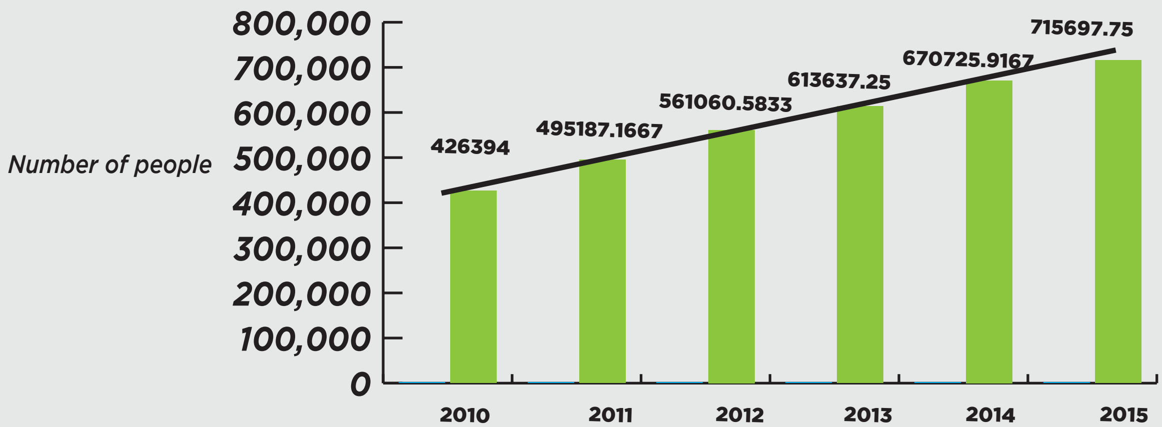
1 For the purposes of this study, and since the industry encompasses various economy activities, Automotive Industry will be define according to the codes 3361 (motor vehicle manufacturing) and 3363 (motor vehicle parts manufacturing) of the National Industrial Classification System in North America (NAICS).

MANUFACTURING SECTOR STRUCTURE IN MEXICO, 2015



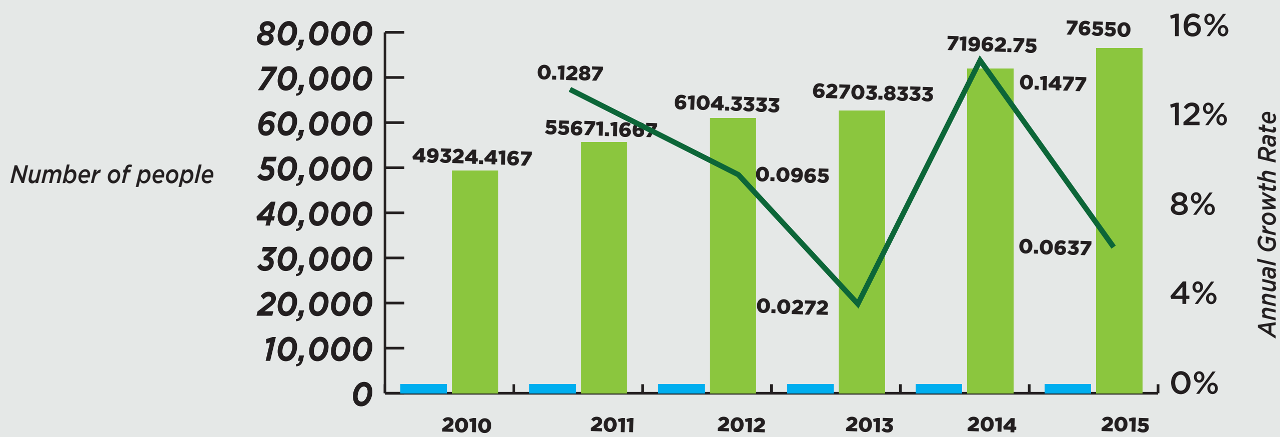
Source: INEGI.

STAFF EMPLOYED IN THE AUTOMOTIVE INDUSTRY IN MEXICO, 2010 - 2015



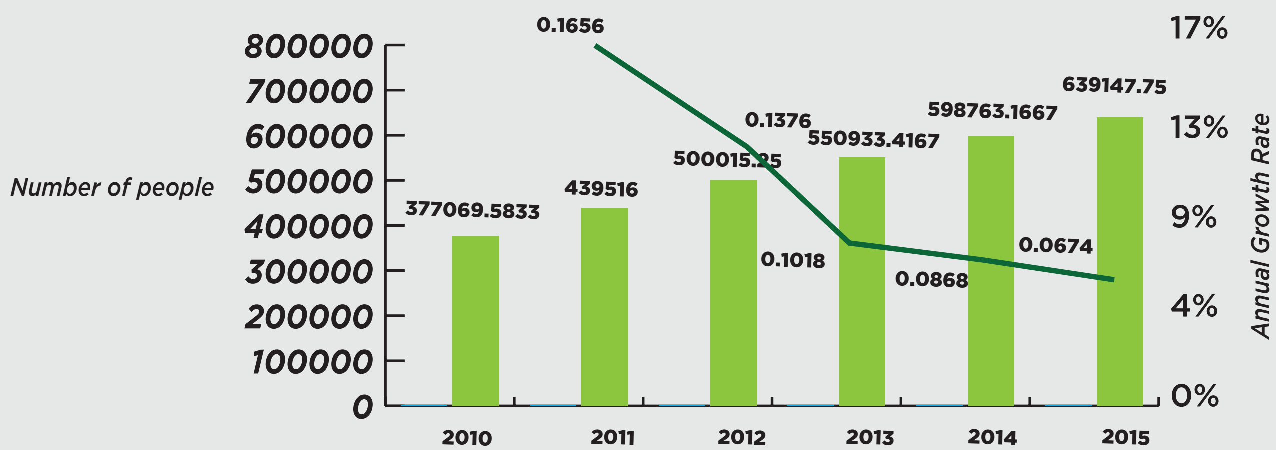
Source: INEGI

EMPLOYED IN THE AUTOMOTIVE INDUSTRY IN MEXICO, 2010- 2015.



Source: INEGI

EMPLOYEMENT EVOLUTION: MOTOR VEHICLE MANUFACTURING



Source: INEGI

4.1.2. ECONOMIC CODES THAT INTEGRATES THE AUTOMOTIVE INDUSTRY IN MEXICO

According to INEGI's figures, in 2015, **the Automotive Sector in México contributed with 29.5% of the total Production Value of Finished Goods (PVFG) in the manufacturing sector,** which represents US$ 107.2 billions.

The Automotive Industry is constituted by 10 economic codes, from which the most relevant are: automobile and light duty motor vehicle manufacturing; light truck and utility vehicle manufacturing; heavy truck manufacturing; motor vehicle gasoline engine and engine parts manufacturing; other motor vehicle parts manufacturing; jointly they represent 79.3% of the Industry's total Production Value of Finished Goods during 2015.

In addition, according to National Statistics Directory of Business Units (DENUE, from its acronym in Spanish), over 1,660 business units converge in this industry. The vast majority of them develop their business in: other motor vehicle parts manufacturing, motor vehicle electrical and electronic equipment manufacturing, motor vehicle gasoline engine and engine parts manufacturing and motor vehicle seating and interior trim manufacturing.

A long with this, the business units that get the best out of their production capacity (PCU) have operations in the following economic codes: motor vehicle transmission and power train parts manufacturing, motor vehicle seating and interior trim manufacturing, and automobile and light duty motor vehicle manufacturing. In contrast, the business units with a lower use of their PCU operate in the next economic codes: motor vehicle brake system manufacturing, other motor vehicle parts manufacturing and light truck and utility vehicle manufacturing.

Another relevant point to be consider is the participation of Small and Medium Enterprises (SME's), due to the number of employees. According to DENUE, SMEs account for 1,036 SME's accounts for 62% of all the business units in the Automotive Sector.[2]

2 The data does not distinguish between Mexican and foreign companies; wherefore it is not to be assumed that all Mexican companies providing services in this segment are included.

MEXICAN AUTOMOTIVE INDUSTRY: STRUCTURE: ECONOMIC UNIT DISTRIBUTION EMPLOYED STAFF, AND PRODUCTION CAPACITY

NAICS CODE	ECONOMIC CODE DESCRIPTION	PVFG	BUSINESS UNITS	EMPLOYED STAFF	PRODUCTIVITY OF EMPLOYEE	PRODUCTION CAPACITY**
336310	Motor vehicle gasoline engine and engine parts manufacturing	10.207	129	45,678	233.447	84.0%
336320	Motor vehicle electrical and electronic equip- ment manufacturing	6.572	404	275,790	23.813	86.8%
336330	Motor vehicle steering and suspension compo- nents (except Spring) manufacturing	2.602	88	18,621	139.788	84.0%
336340	Motor vehicle brake system manufacturing	1.012	108	20,471	49.452	86.1%
336350	Motor vehicle transmis- sion and power train parts	5.024	63	30,553	164,420	83.2%
336360	Motor vehicle seating and interior trim manu- facturing	3.392	205	89,123	38,050	91.1%
336370	Motor vehicle metal stamping	3.621	186	25,898	139,788	89.8%
336390	Other motor vehicle parts manufacturing	10.053	417	133,015	75,532	83.6%
336110	Other motor vehicle parts manufacturing	48.156	24	58,044	829,659	83.2%
336120	Heavy duty truck manufacturing	107.219	36	715,698	894.797	86.9%
	TOTAL AUTOMOTIVE	107.219	1,660	715,698	149.792	84.5%

Source: INEGI
PVFG Figures in billion dollars, at current prices
Business Units correspond to the total unit recorded i
*n the DENUE, according to the NAICS classification. *The value isexpressed in thousands of dollars.*
***The value is average of the percentages published during 2015 at the Monthly Manufacturing Industry Survey (EMIM, due to its acronym in Spanish).*
Figures in dollars were calculated using the exchange rate published by the Federal Reserve Economic Data (15.874pesos/USD).

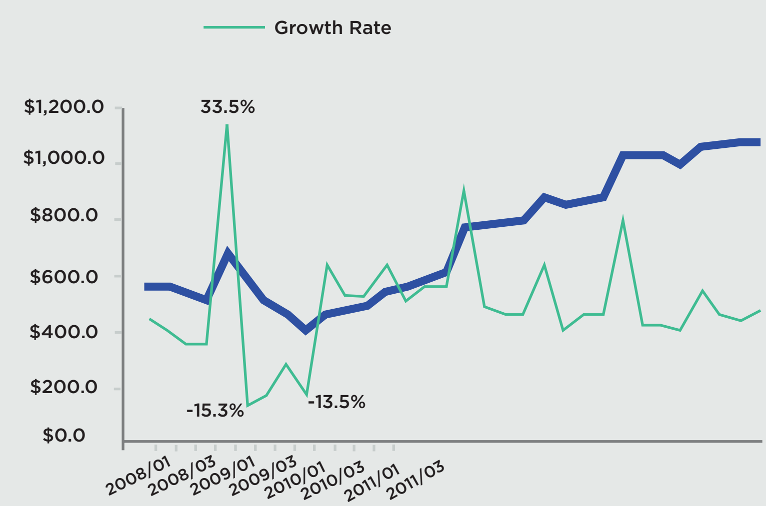
According to the figures above, workforce average productivity in t**he Mexican Automotive Sector is highly competitive on a global scale, it surpass the US$ 100,000 per employee,** figure that is significant greater in niches, such as trucks and tractors manufacturing units, in where the productivity surpasses US$ 894,000 per employee. ***Particular subsectors productivity indexes far below US$ 40,000 per employee, this situation highlight opportunity areas that require special treatment.***

4.2. ANALYSIS OF THE AEROSPACE INDUSTRY IN MEXICO

4.2.1. GROSS PRODUCT AND OCCUPATION

Regardless of not being an outstanding sector in terms of total economic value in the Mexican manufacturing industry (or in the national economy), **the Aerospace Industry has presented a solid and constant growth in the past few years** (chart A). Another relevant aspect to consider is the evolution of its share in the Gross Value Added (GVA) in the manufacturing industry, which in 2010 accounted for 0.4% of the GVA and it increase to 0.7% in 2015, figure that represent a CAGR of 11.8% during that period. Given its contribution to the manufacturing industry GVA in 2015, the industry is positioned within the 23 economic activities that contribute between 0.5% and 0.9% of the GVA.

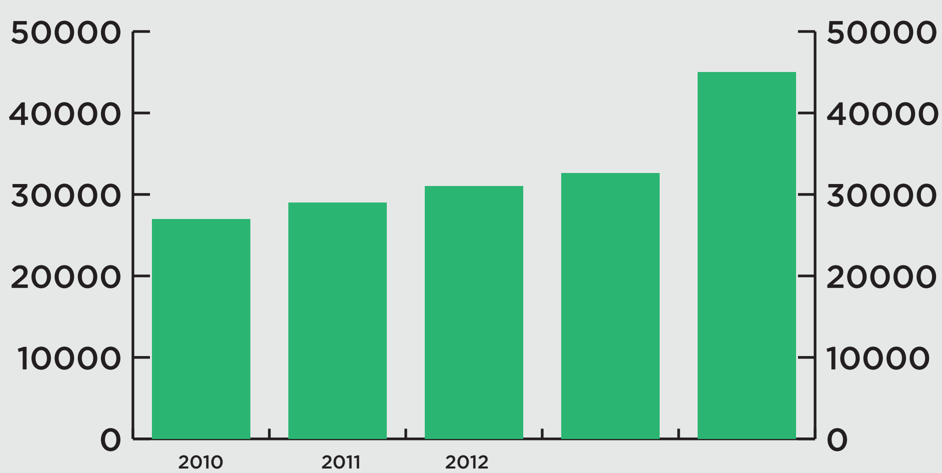
CHART A
AEROSPACE INDUSTRY EVOLUTION IN MEXICO 2008-2015



Source: INEGI. *Figures in million of dolars.*

In terms of employment, the Aerospace Industry accounted for 45,000 direct jobs in 2014.

STAFF EMPLOYED IN THE AEROSPACE INDUSTRY IN MEXICO, 20120 - 2014

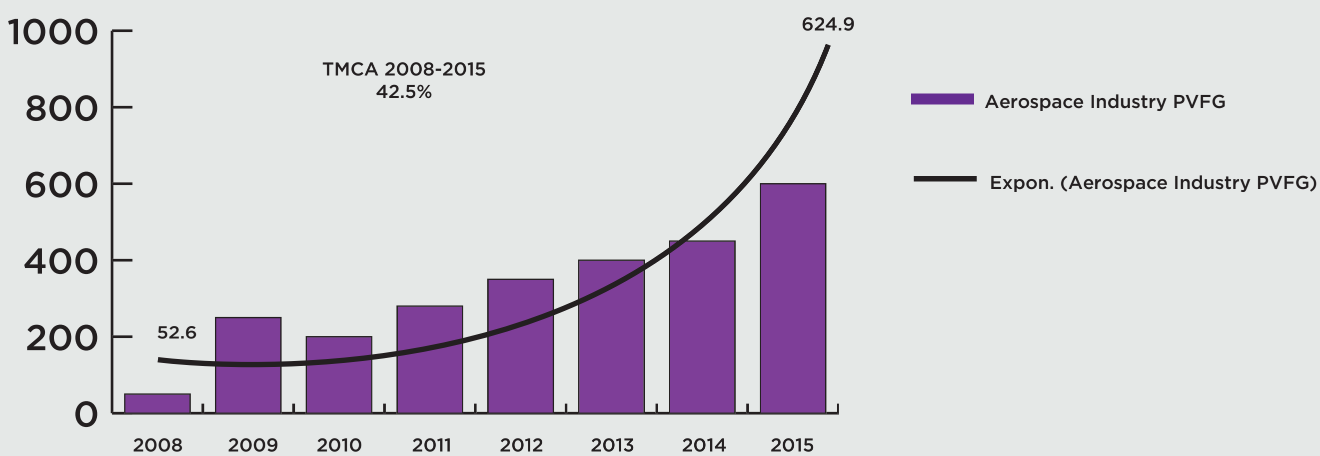


Source: ProMéxico

4.2.2. GROSS PRODUCT AND OCCUPATION

The PVFG of the industry has increased constantly in the last years. During 2009 it increased its value three times when compared to the previous year figure. In subsequent years, **this indicator has shown a constant growth trend due to the boost created by foreign investment in the area, and the implementation of different government promotion programs**, such as the Strategic Program for the Aerospace Industry.

AEROSPACE'S INDUSTRY PVFG EVOLUTION

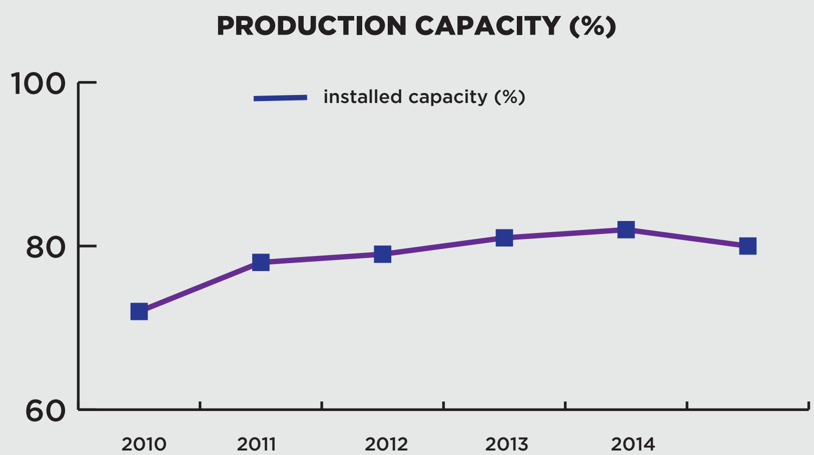


Source: INEGI. Figures in million dollars, at current prices.

According to INEGI's figures, **in 2015 the Aerospace's Industry Production Capacity reported an average use of 81.5%. This high utilization of the Production Capacity is related to the state of the art technology required by the industry and skilled labor force, which is essential to the production of highly specialized manufactured goods.**

Furthermore, according to ProMéxco's figures, it is estimated that the Aerospace Industry in Mexico consists of 307[3] business units, a figure that present a 91.9% growth rate when compare with 2008 records.

PRODUCTION CAPACITY IN THE AEROSPACE INDUSTRY, 2010 - 2015



Source: Own development with INEGI figures.

The most relevant fact for I4.0 from the aerospace industry is the great capacity displayed by the country for reconverting productive lines and assimilating technologies in record times. This demonstrates the flexibility of national supply chains, and the adaptability of Mexican manufacturing systems to create a highly sophisticated industry, such as the aerospace industry in just a few years.

3 The number of units were taken from ProMéxico

4.3. ANALYSIS OF THE CHEMICAL INDUSTRY IN MEXICO

4.3.1. GROSS DOMESTIC PRODUCT AND OCCUPATION

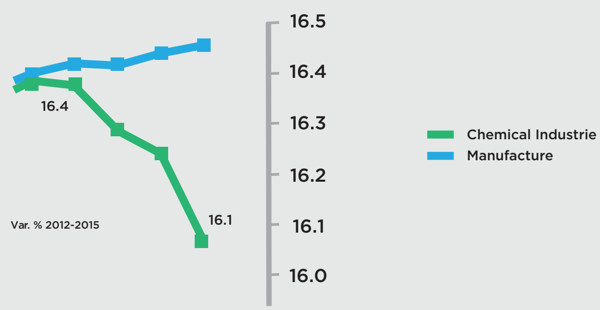
According to INEGI and NAICS, the Chemical Industry is integrated by seven economic activities, which includes plastics material and resin manufacturing; pharmaceutical and medicine manufacturing; pesticide and other agricultural chemical manufacturing; paint and coating manufacturing among others.

In 2015, the Chemical Industry contributed with 1.8% of the Mexican GDP, along with 10.8% of the GVA of the manufacturing industry.

On despite of its relevance, this sector showed a decrease of 1.3% in its contribution to the GVA between 2009 and 2015. The inflexion point took place in 2012, year in which China's economy started to slowdown, and with it a decrease on the demand of products from Latin America.

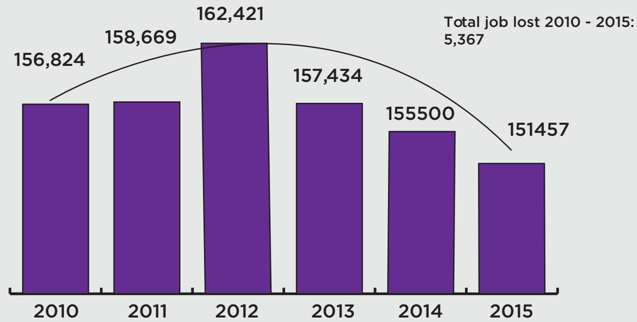
In terms of employments, the Chemical Industry ranked seventh in terms of number of jobs, **accounting for 4.3% of the total labor force in the manufacturing employment.** Additionally, between 2010 and 2015, the employed staff in the chemical industry decreased from 156,824 to 151,547 jobs.

GVA IN MANUFACTURING AND CHEMICAL INDUSTRIES, 2009-2015



Source: INEGI.

EMPLOYMENT EVOLUTION IN THE MEXICAN CHEMICAL INDUSTRY



Source:INEGI.

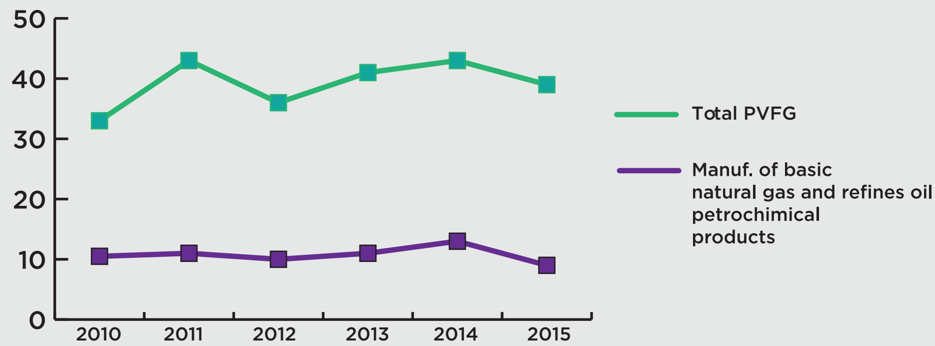
4.3.2. ECONOMIC CODES THAT INTEGRATES THE CHEMICAL INDUSTRY IN MEXICO

Among the economic codes that integrates the Chemical Industry the petrochemical manufacturing contributed with the greatest percentage to the PVFG in 2015, with 20.6%, followed by the manufacturing of pharmaceutical compositions (16.6%), and the manufacturing of synthetic resins (12.2%). In contrast, the economic classes with the least contribution were: manufacturing of matches (0.1%), manufacturing of films, plats, and photosensitive paper for photography (0.3%), as well as the manufacture of synthetic pigments and dyes (0.6%).

The Chemical's Industry PVFG fell by 6.8% between 2014 and 2015. This slowdown was due to a decrease in the production of segments such as photographic film, paper, plate, and chemical manufacturing (-22.0%), and the petrochemical-manufacturing(-35.0%). The decrease in the PVFG of this last segment is directly related to the drop in oil prices.

On the other hand, when analyzing the use of the Installed Capacity in the industry's economic classes, it was found that the manufacturing of films, plates, and photosensitive paper for photography made a moderate use of such capacity (only 55.0%), while the manufacture of synthetic pigments and dyes employed 85.8% of its capacity.

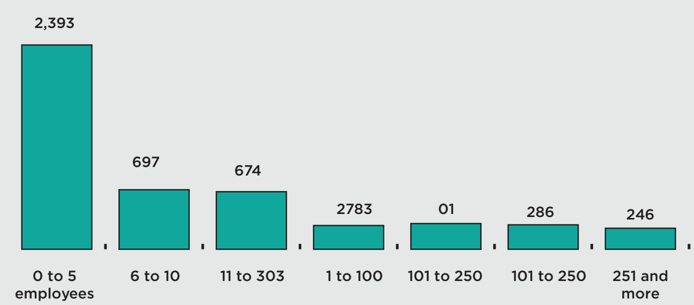
VPFP EVOLUTION IN THE CHEMICAL INDUSTRY,2010-2015



Source: INEGI.

Another point to consider is the share of business units that, due to their employed staff, may be regarded as Small and Medium Enterprises. In the Chemical Industry, according to the DENUE, there are 4,629 business units that correspond to this category; that is, 95% of the total business units recorded for the segment.

BUSINESS UNITS WITHIN THE CHEMICAL INDUSTRY BY ENTERPRICE SIZE



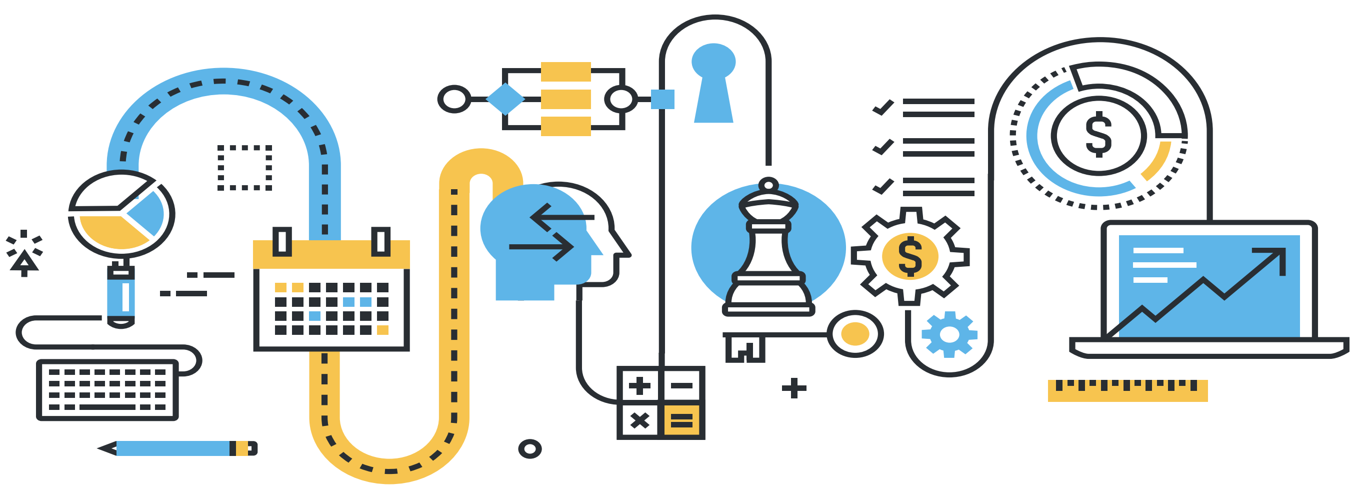
Source: INEGI.

Chapter 5.

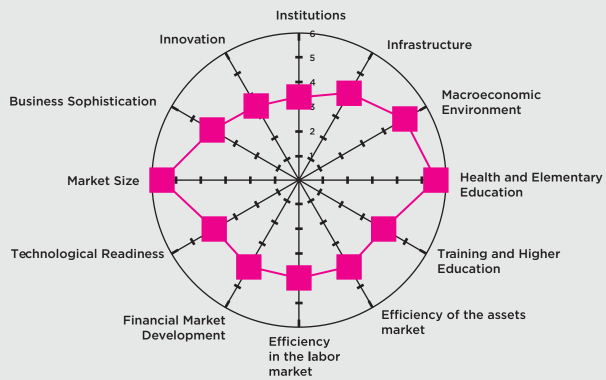
MEXICO ON THE PATH TO INDUSTRY 4.0

5.1. TECHNOLOGICAL INNOVATION AND PREPARATION

According to the Manufacturing Competitiveness Index (Deloitte), Mexico ranks 13th for 2018. Although the country has acceptable grades in some of the pillars that integrate the index, it must be admitted that, in terms of innovation; technological preparation; education, and training; grades were unsatisfactory.



MEXICO'S PERFORMANCE IN CGI 2015-2016



Source: Global Competitiveness Index, 2015-2016, WEF.

Even though it is a country that produces several manufactured goods, and high and medium technology goods, Mexico is not recognized as a leader in innovation. In this GCI pillar, the most notorious deficiencies are in the following subsections: innovation capacity; Research and Development (R&D) company expense; government procurement for acquisition of advanced technology products; and availability of scientists and engineers.

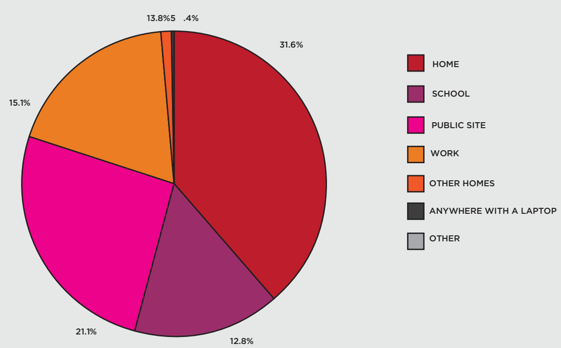
In terms of technological readiness (ninth pillar of the GCI), Mexico ranks 73rd. It must be acknowledged that the country recorded a better performance compared to previous editions, improving in areas such as: availability of recent technologies; technology absorption on a firm level; and Direct Foreign Investment and technology transfer; to enumerate some of them.

5.2. THE USE OF INFORMATION AND COMMUNICATION TECHNOLOGIES IN MEXICO

According to ENDUTIH (2015), currently 55.735 million Mexicans[1] have used a **computer; this represents 46.1%** of the total population. **The main place** of access to computers by users is the home, followed by public sites and work places
.

1 The ENDUTIH data correspond to May 2015.

COMPUTER USERS BY PLACE OF ACCESS



Source: ENDUTIH.

Another relevant factor to take into consideration is the number of Internet users, area that recorded **62.448 million Mexicans with access to the network.**

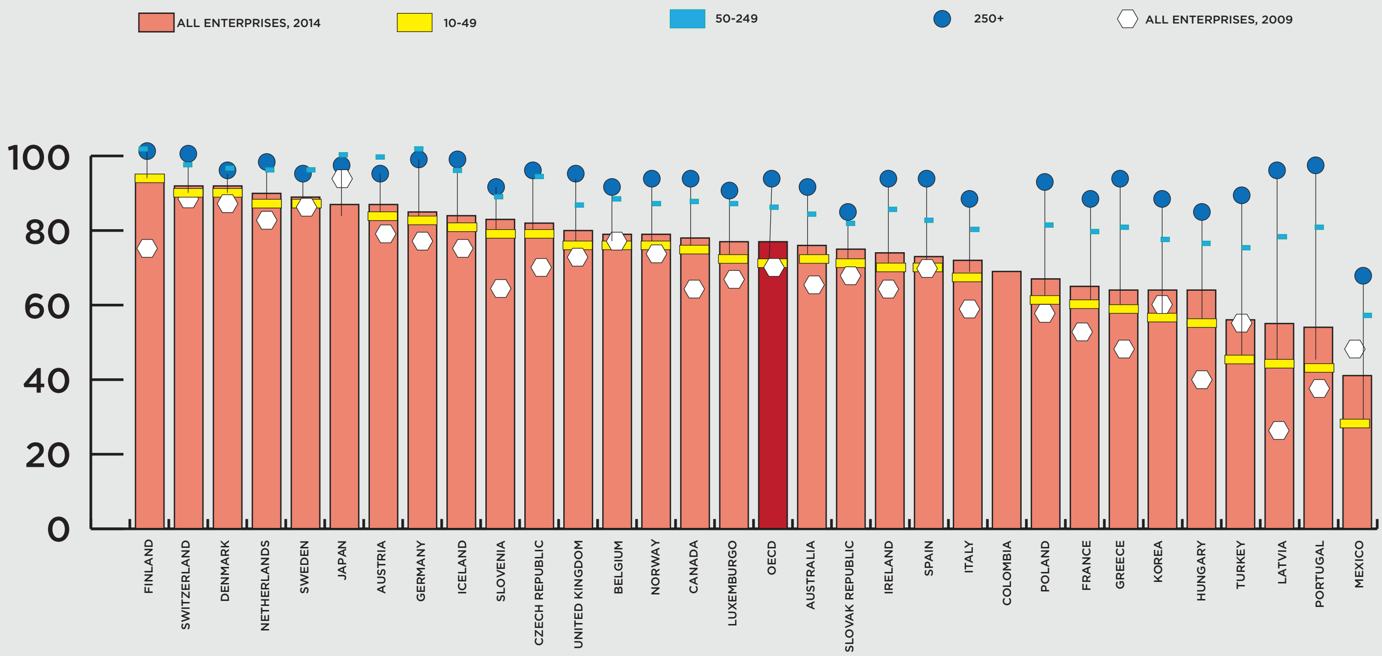
Among the main uses of the internet by Mexicans in 2015, according to ENDUTIH encompasses 11 categories, including information queries, communication, access to visual contents, access to social networks, as well as entertainment.

In terms of ICT usage, mobile communication devices (cellphone) is the most widely used channel in the country, approximately 77.711 million people have used them[2]. In addition, only 44.479 million Mexicans confirmed the usage a smartphone, out from which 29.846 million confirmed to have an active connection to mobile Internet through this kind of devices, while 14.588 denied the usage of mobile connection service in their smartphone.

In terms of the use of I.40 applications in the industry, it is worth noting that Mexico does not make an intensive use of these tools. An example of this is the number of companies that have a specialized website or web portal (illustration 1). In that regard, Mexico is still below the average recorded by **OECD countries, this represents a great challenge for the adoption of information technologies, such as the I4.0 solutions development platform.**

2 According to the ENDUTIH, a user of mobile phone is considerate as any individual of 6 years or older that communicated with someone else with the use of a cellphone in the last year; whether if it was an caller or a receiver . Therefore, it must not be assumed that the figure corresponds to individuals that own a cellphone.

COMPANIES WITH A WEBSITE



Source: OECD.

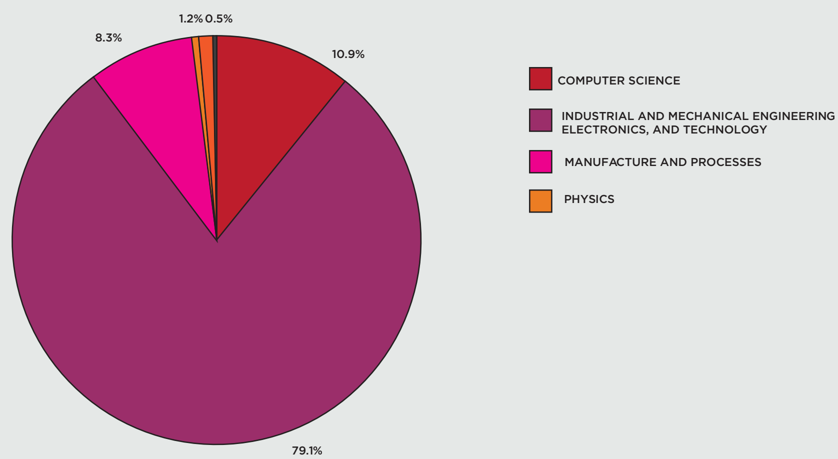
5.3. DEVELOPMENT OF INDUSTRY 4.0-FOCUSED TALENT IN MEXICO

According to data from the Statistical Higher Education Yearbook, for school cycle 2014-2015, 987,317 students were enrolled in educational programs related to engineering, manufacturing, and construction, on both bachelor and technical level. The states that reported a higher number of students enrolled in such areas were Mexico City, Estado de Mexico, and Veracruz. It is worth noting that a large portion of the students are enrolled in industrial engineering, mechanics, electronics, and technology, followed by specializations in manufacturing and processes; these areas concentrates 75.6% and 6.7% of the students enrolled. Additionally, the number of students enrolled in academic programs related to computer sciences, mathematics and statistics, and physics were 85,590, 18,846, and 7,226, respectively.

In regards to the number of graduates for 2014-2015 scholar period, **128,427 students completed their studies, from which Industrial engineering, mechanics, electronics, and technology accounted the largest number of graduates (80.9% of the total),** followed by computer sciences (10.5%), and manufacturing and processes (8.3%). As a contrast, mathematics and statistics, as well as physics, were the areas with the lowest number of graduates recorded for the period (0.4% and 1.5%, respectively).

According to the National Associaton of Universities and Institutes of High Education (ANUIES, by its acronym in Spanish), during the 2014-2015 scholar cycle, 96,868 students obtained their bachelor degrees in the fields mentioned above fields in the following proportion:

STUDENTS GRADUATED UNDER 2014-2015 SCHOOL CYCLE (EDUCATIONAL FIELD SELECTED)



Source: ENDUTIH.

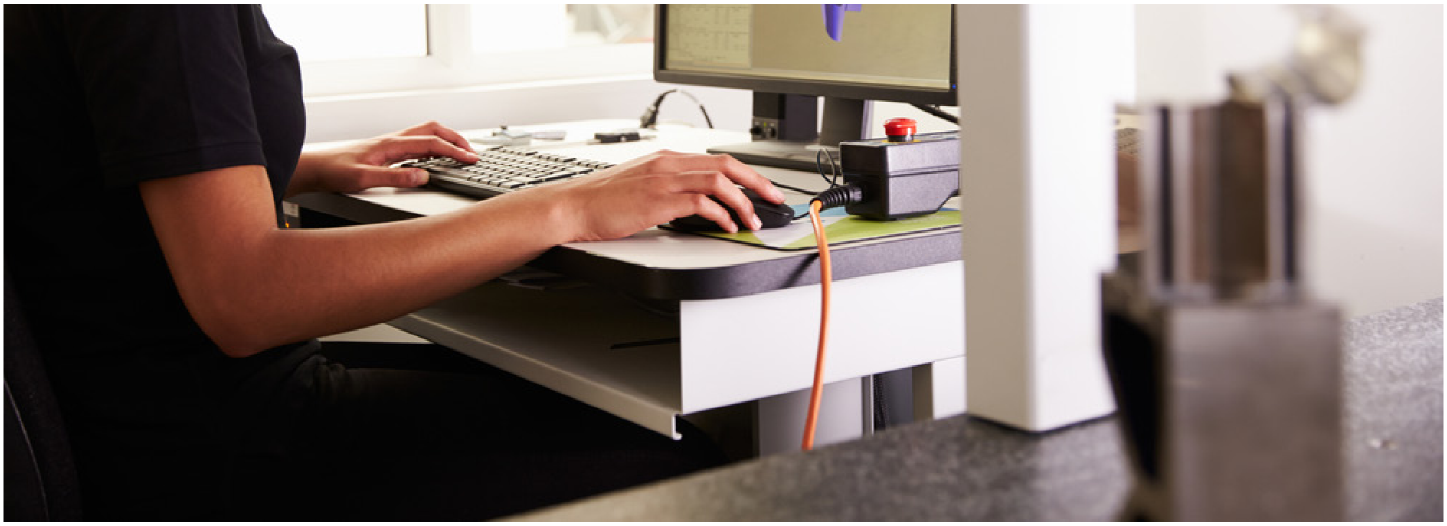
The educational areas that were identified **with a major affinity towards Industry 4.0 are: computer sciences; mechanical engineering; electronics and automation; physics; and mathematics and statistics. Jointly, these areas recorded a total of 566,696 individuals enrolled** during the 2014-2015 scholar cycle. Additionally, during this period, 81,396 finished their programs, and 61,996 obtained their bachelor degree.

5.4. CURRENT PROJECTS AIMED TO IMPROVED AND SPECIALIZED ADVANCE MANUFACTURING IN MEXICO

5.4.1. CORPORATIVE INITIATIVES

INTEL: INTER DESIGN CENTER IN MEXICO, IN GUADALAJARA

The global processors company invested US $ 170 millions in the Intel Design Center located in the Zapopan, Jalisco. The human capital working in this center is approximately 1,000 people, between Intel experts and researches, as well as specialized high-engineering students.



CONTINENTAL AUTOMOTIVE-INNOVATION AND DESIGN CENTER IN JALISCO

This center was established to develop security and comfort products for automobile users; connectivity and interaction with the driver; entertainment inside the vehicle, and control devices such as engine and braking systems. It is expected that in the next five years one thousand engineers will develop high quality technologies for the automotive industry.

HONEYWELL: HONEYWELL ENGINEERING AND DESIGN CENTERS IN BAJA CALIFORNIA AND CHIHUAHUA

The Chihuahua Engineering and Design Center has more than 32 thousand square feet, including a 14 thousand square feet laboratory and 74 employees; which adds to the install capacity of the center located in Mexicali, Baja California. **The Chihuahua facilities were developed to design test equipment, design mechanical engineering equipment, electronics engineering, embedded software development, product validation, and manufacturing support.**

5.4.2. GOVERNMENT INITIATIVES

— CIMAT

Some research areas related to Industry 4.0 developed in this research center are:

- Robotics in terms of planning of movements and perception for mobile robotics, feasible movement conditions for mobile robots in external environments, and robot visual control.
- Analysis of multidimensional data and pattern recognition. It refers to statistical modeling; exploration, prediction, and classification of big data; automatic learning, information transmission, databases and data mining, and pattern recognition.

INNOVATION APPLIED TO COMPETITIVE TECHNOLOGIES CENTER (CIATEC, BY ITS ACRONYM IN SPANISH

In 2013, the CIATEC open the airbag-testing laboratory with the main purpose of evaluating and validating passive security systems in a controlled environment. This laboratory is aimed to decrease the costs and time of assembly plants in the region, as well as performing tests abroad. This center, located in Leon, Guanajuato, performs more than 350 tests for the automotive sector under international quality regulations and certifications, that allows the center to provide services to the main assembly plants located in the country, such as: VW, Nissan, Ford, GM, Honda, and Mazda.

ENGINEERING AND INDUSTRIAL DEVELOPMENT CENTER (CIDESI, BY ITS A CRONYM IN SPANISH)

It is a research and industrial development center part of CONACYT Research Centers. In terms of advanced manufacturing, it provides technological services for the aeronautic and automotive sectors, such as: design and building of parts and test bench equipment. On the other hand, in terms of innovation and manufacturing process development, the center does research in flexible manufacturing, intelligent manufacturing, high mix and low volume manufacturing, among others.

INFOTEC/FIWARE: NATIONAL LABORATORY OF THE INTERNET OF THE FUTURE IN AGUASCALIENTES (LANIF, BY ITS ACRONYM IN SPANISH)

It is a government initiative part of the network of centers of CONACYT. It seeks to create an experimental and productive innovation ecosystem consisting of hardware and software infrastructure, in where colleges, research centers, cities, companies, and other organizations can experiment with the use of technologies related to the internet of the future: IoT, Big Data, and cloud computing.

CIATEQ

It is an organization part of CONACYT's specialized centers in advanced manufacture with national coverage through their headquarters in 8 states and more than 3,600 linked projects, providing more than 44,000 technological services for 3,400 customers. Its areas of specialization are: IT, electronics and control, measurement systems, mechanical systems, engineering and plant development, virtual engineering and manufacture, plastics, and advanced materials.

5.4.3. PUBLIC-PRIVATE INITIATIVES

THE VOLKSWAGEN GROUP/BENEMÉRITA UNIVERSIDAD AUTÓNOMA DE PUEBLA (BUAP)/PUEBLA STATE GOVERNMENT: INTER-INSTITUTIONAL COMPLEX OF EDUCATION

It is a project focused on the development of human resources in engineering and technology areas related to the automotive industry under the dual education scheme, which is supported by the Puebla's Government, BUAP, and Volkswagen / Audi. In consists of a collaborative space, in where students and scholars will be integrated to mobility and advanced manufacturing programs with other educational institutions and companies, both national and international.

Some of the degrees to be offered by the CIFIIA and supported by BUAP are: Automation and Autotronics Engineering, Industrial Information; and Process and Industrial Management Engineering.

5.4.4. COMPLEMENTARY ROADMAPS FOR INDUSTRY 4.0

5.4.4.1. Internet of Things

The global relevance of communication in real time between objects through the use of Internet networks, that allows the collection of information and data to turn it into knowledge, known as the Internet of Things (IoT), has incentivize countries to promote initiatives aimed to develop this sector. In regard of the global trend, it is important to define a strategy that allows Mexico to position itself in a global market; this is the main reason why the Federal Mexican Government, in coordination with the World Bank, CANIETI, and INNCOM, promoted the development of a Roadmap for the Internet of things.

5.4.4.2. Design, Engineering and Advanced manufacturing

With the purpose of promoting the cross-develop of ideas to find adequate solutions for the industry needs, it was proposed by the trust group, which participates in the elaboration of this Technology Roadmap (TRM), to include relevant players on both supply and demand areas of advance manufacturing. The areas of experience of the proposed players for the development of the TRM include: Information Technologies (IT); electronics and mechatronics engineering; robotics; automation and control; virtual manufacture and process simulation; among others.

5.4.4.3. Puebla: Capital of innovation and design

ProMéxico, the Federal Mexican Government agency in charge of FDI attraction and exports promotion, acknowledged the importance of considering that any design project should find favorable environment for its development in the community where it is developed. This idea led to the conception of a Design Ecosystems Technology Roadmap (DTRM). The DRTM provides a nation-wide action plan for the use of design as a driver to development within a creative ecosystem.

Puebla is currently developing a creative design ecosystem through the project Puebla: Capital of Innovation and Design (PCID, by its acronym in Spanish). The PCID project is aimed to boost its impact and transmitting its benefits to the population, bringing life to a region supported by a design ecosystem.

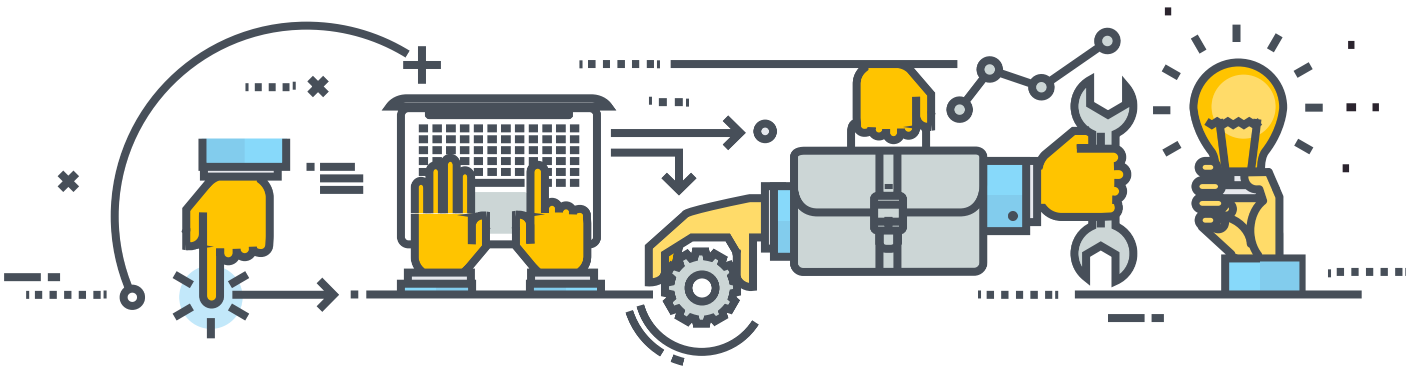
5.4.4.4. Urban Operating Systems

Through this Roadmap, the goal is to detect the feasibility of establishing operating systems as a standard for the development of Smart Cities in Mexico and, to turn programming and innovation into competitive advantages for the international software development environments.

The scope refers to the application of Urban Operating Systems in the design of Smart Cities, addressed from a national perspective, and that should be complemented with a sub-national vision (states and municipalities).

Chapter 6.

INDUSTRY 4.0 ROADMAP



6.1. STRENGTHS - WEAKNESSES - OPPORTUNITIES – THREATS ANALYSIS (SWOT) FOR INDUSTRY 4.0

The Strengths – Weaknesses – Opportunities – Threats Analysis (SWOT) allows us to have a view of the general landscape of the scenario in Mexico, while also identifying whether the country is prepared to implement the digitalization and automation model. Furthermore, it provides a vision of the country's areas of opportunity to develop this model, detecting strategic markets and policies for developing the economy through the use of the I4.0 model. Likewise, it helps to identify topics in which the country must place great efforts, describing its deficiencies and advantages in terms of infrastructure or human capital, necessary to complete the digital and automation transition.

General Observations

Mexico has 23 Information Technology clusters in 27 States, which encompass 1,340 players, jointly reporting an accumulated billing of $2.1 billion dollars. Likewise, according to the Ministry of Economy, there are 30 tech parks in the country specialized in Information Technologies and business processes, built through partnerships between the public and private sectors and the academy. However, there is a poor link between the academy and the industry and, therefore, to rapidly boost this sector, the establishment of collaboration programs between its members is essential.

Considering previously developed roadmaps to define strategies on digitalization and automation, it was decided to use an integrated SWOT analysis related to industry 4.0.

STRENGTHS

Domestic ICT companies have been identified as an important driver of the emerging sector, due to their knowledge of the national market and near shore advantages. The capabilities and experience of these companies are essential for the development of Industry 4.0.

OPPORTUNITIES

According to A.T. Kearney, Mexico ranked second in Latin America as a FDI destination in ICT projects, attracting 23% of the region total investment. The country is recognized as an attractive market to develop IoT and related applications aimed to be used on strategic sectors (such as intelligent manufacturing)

WEAKNESSES

The greatest challenge is to promote a fair playing field and technological neutrality between the different players in the market to promote competition and innovation. Lack of leadership and industry coordination are other challenges to develop I4.0 in Mexico, especially for an emerging sector not fully understood by key players.

THREATS

Limited access to capital, due to an underdeveloped financial system, proves to be a major barrier for innovation and growth, mainly for SME's which are not able to reach their full potential in the market. Data protection, corruption, and intellectual property remain as important concerns of companies in Mexico.

STRENGHS

Political willigness	Infrastructure: 250K access points
Amount and availability of human resources	Automotive industry as a mature strategic sector
Aligment of interest between skateholders for the development of IoT/industry 4.0	Wide academic offer to generate specialized talent
Growing service economy	Understanding of the national environment (holistic vision to implement Urban Operating Systems)
High-technology industries for demand generation	Competitive prices
Increasingly automated manufacturing industry	Availability of creative human resources
Mexico, second largest market in LATAM	Government support programs specific tothe industry
Development of small and medium business units associated with production processes of large companies that may enter production systems for Industry 4.0	The electronic industry is positioned as an exporting leader of highly sophisticated goods

OPPORTUNITIES

ICT as a cross side industry represents an opportunity for strategic sectors	lobal trend to create intelligent factories
Growing demand for intelligent system applications	Costs redefinition within the value chain
Collaboration between the academy and productive sectors	IoT will increase the global competitiveness within the Industry 4.0 framework
Strong economic links and geographic proximity with the United States	Boost on regional development
Mexico is the 10 largest economy in the world (PPP) and one of the most relevant manufacturing economies	Telecommunications legal framework reform
Room for domestic market growth	Competitive skilled labor force cost

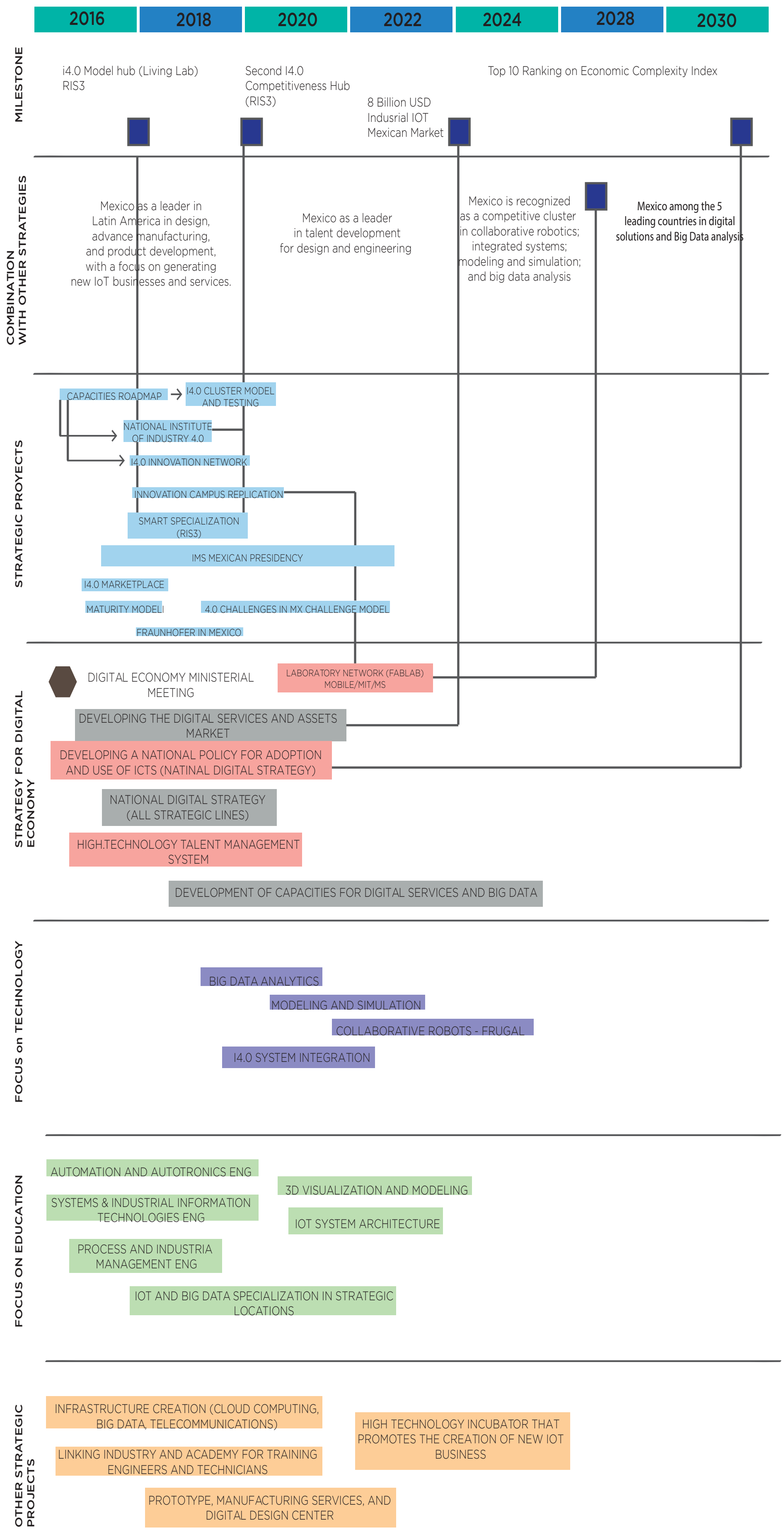
WEAKNESSES

nefficient regulatory framework	Insufficient and deficient technological infrastructure
Low access to internet and high-bandwidth	Undeveloped internal market
Low rate of collaboration between academy and industry	Deficient innovative environment
Lack of specialization and experience in the industry	Lack of a national long-term strategy to develop the industry 4.0
Low rates of investment and IT adoption	Lack of public policies designed to promote industry 4.0
Absence of educational programs specialized in digitalization and automation	Absence of a multi-disciplinary vision
Limited access to capital and credit	Low propensity of Mexican companies to developed their own technology
Low awareness of Ind us try 4.0 and its applications among companies	
Misalignment between academy and industry	
Weak support to inventions and patent registration	

THREATS

Priority to technology acquisition over development of own technology	Lack of access to financial resources for SMEs
he risk of being left behind in the use and applications related to Industry 4.0	Nonexistence of a Development Commission or specific entities to assist the Industry 4.0
Data theft and cyber-security	Initial pilot programs should be considered
Low inflows of FDI due to in security perception	Absence of a common vision for legal reforms to the applicable legal framework
Global systems with no interoperability	Low diffusion of Industry 4.0 best practices in clusters and technological parks
Technological slowdown as a consequence of interests of non-related third parties	Other countries with lower production costs
Undefined legal framework	Influence of the American policies in the economic and industrial sector

6.2. INDUSTRY 4.0 ROADMAP



6.2.1. ANALYSIS OF MILESTONES AND STRATEGIC PROJECTS FOR INDUSTRY 4.0

I. In 2019 and 2021, Mexico will build up two hyper-flexible manufacturing clusters. The clusters will develop an I4.0 framework and a Manufacturing Operating System.

a. **I4.0 cluster framework**

A general framework must be developed in order to support the creation of a hyper-flexible manufacturing operating systems, this will be the platform for systems integration and applications development. These clusters should be supported according to the regional productive vocations and using the current infrastructure and capabilities, as well as the existing projects and collaboration mechanisms which include: price clubs; supply information systems; shared infrastructure; and technology packages; among others.

b. **Innovation Campus replication for I4.0**

Identifying regions that fulfill the requirements to reply the innovation campus model developed by Continental and Volkswagen in Mexico whose main objective is to establish a collaborative environment between the academy and the private sector to develop innovation projects in Industry 4.0.

c. Fraunhofer TTO in Mexico

Fraunhofer's technology transfer office in Mexico will start operations focused on the development of I4.0 projects for Mexico and other emerging economies. This collaboration model with Germany may serve as a basis for exploring other international cooperation programs, with countries interested in I4.0 project implementation.

d. I4.0 Maturity model

The execution of Industry 4.0 strategies requires the analysis of the innovation capacities of clusters and companies. It is necessary to classify them according to their ability to adopt and implement I4.0 projects in Mexico. This will provide the tools needed to design public policies and incentives required to improve the competences of the clusters and companies. This analysis will help to identify the gaps between large companies and SMEs and, to create strategies to make them converge into common solutions and a shared vision of I4.0 evolution.

e. IMS Presidency in Mexico

Mexico will host the presidency of the IMS, an international organization that leads the manufacturing industry trends, and enables the international cooperation mechanisms aimed to solve the main cha- llenges that the industry faces. In addition, the IMS analyses the impact of the digital economy and sharing economy in the manufacturing industry. As a host president, Mexico would focus international efforts towards the development of an I4.0 model centered in human-centered and collaborative manufacturing and design.

II. In 2025, the Mexican IoT market will represent 8 billion dollars (as market share of the world's manufacturing exports).

a. Competence map

Unified data bank of businesses, research centers, and higher education institutions operating in Mexico according to their productive and innovation capacities for reconfigurable, adaptive, collaborative, non-hierarchical, and hyper-flexible manufacturing. The roadmap should take into consideration the existing infrastructure and talent available for developing I4.0 strategies.

b. Research and Innovation Strategies for Smart Specialization (RIS3)

Development of complementary strategies aligned to the regional innovation agenda established by CONACYT, through the identification and development of regional productive vocations for ICT clusters and strategic sectors.

c. Challenges regarding I4.0 in the Mexico's model Reto México

Identifying major national challenges for the development of value-added manufacturing capabilities, and promoting I4.0 solutions, such as IoT, augmented reality, sensors and robots; supervision of manufacturing and complex systems analysis, for example: modeling, simulation, prediction and artificial intelligence tools.

III. In 2030, Mexico will rank among the top ten in the Economic Complexity Index published by Harvard University and MIT.

a. National Institute of Industry 4.0

It is a public-private entity in charge of the development, coordination and implementation of national strategies. The institute will propose public policy recommendations to boost the inter-institutional collaboration system in order to integrate Mexico as an emerging leader of the Industry 4.0 paradigm.

The institute should act as a central hub and intelligence unit of the national Industry 4.0 environment aimed to connect and coordinate players and ideas. In addition, it will communicate and spread sectorial analysis and best practices.

b. Innovation network for Industry 4.0

A collaborative network of key players in I4.0 topics should be developed, with the purpose of improving innovation capabilities in Mexico. The network must be connected to global networks and challenges.

c. National policy for adoption and use of ICTs in the National Digital Strategy.

According to the National Digital Strategy, "public policies shall be created, aimed at boosting the supply and demand of digital assets and services, as well as the adoption of ICTs in economic processes."[1]

d. Development of the digital assets and services market: Market Place I4.0

Establishment of a Business-to-Business (B2B) platform to link supply and demand of I4.0 services and products. The open digital platform will be used for the identification and deployment of industrial challenges, I4.0 solutions and stakeholders. Such platform should be a space of negotiation between I4.0 solution suppliers and

1 National Digital Strategy, 2013.

consumers that promote the convergence of strategic sectors and technology industries; this platform will have the purpose of increasing productivity and added value for national manufacturing sector and integrating them into the international market.

e. **Digital Economy Ministerial Meeting**[2]

The Internet has grown and diffused rapidly across the globe, bringing significant benefits to economies and societies. Enhancing access and participation in the digital economy requires collaboration amongst all stakeholders and for governments to find new approaches to policy development. On 2016, Ministers will gather in Cancún, Mexico, for the OECD Ministerial Meeting on the Digital Economy, to continue the dialogue and keep our nations moving forward, together, in this digital era.

f. **National Digital Strategy**[3]

The National Digital Strategy, "Digital Mexico," is the digital action plan the Government will implement over the next few years. This strategy was devised to meet the need to harness the potential of Information and Communication Technologies (ICTs) as a catalyst for the country's development. The incorporation of ICTs into every aspect of the everyday lives of people, organizations and government has multiple benefits that translate

2 OCDE. Digital Economy: Innovation, Growth and Social Prosperity.
3 National Digital Strategy, 2103

into improvements in the quality of life.

6.3. MERGING WITH OTHER STRATEGIES

1. Mexico, as a leader on IoT applications in Latin America in design, advanced manufacturing, and product development, with a focus on generating new IoT businesses and services.
    a. Infrastructure development (cloud computing, big data, telecommunications, etc.) for designing and implementation of IoT applications.
    b. Set up of a network of Living Labs and Ma- ker Spaces such as Fab Labs and Tech Shops.
    c. High tech business incubator focused on IoT projects.
    d. Promote the dialogue between academy and industry to improve engineers and technicians academic curriculum according to the industry needs.

2. Mexico among the 5 leading countries in digital solutions and Big Data analysis in 2025.
    a. Development of an IoT-specialized support scheme.
    b. Design of an IoT and big data specialized education program in strategic regions (Guadalajara, Monterrey, Querétaro, Mexico City and Puebla).
    c. To create a world-class national cluster network for IoT in accordance with the RIS3 model.

3. Mexico is recognized as a competitive cluster in collaborative ro-

botics; integrated systems; modeling and simulation; and big data analysis.

a. Gather information to identify Mexico's current capabilities.

b. Promote the creation of multiple fast prototyping development centers, for manufacturing and digital design services as a tool for developing innovation and industry capabilities in IoT and I4.0.

4. Mexico as a leader in talent development for design and engineering

a. Framework to strengthen specialized talent formation and entrepreneurial skills.

b. Design a framework to boost the production of intangible assets and an environment to support entrepreneur's needs.

5. Talent management

DRIVERS	STRATEGIC ACTIONS
Identify global demand and locate regional potential to attend I4.0 opportunities	*Select six states with the potential for implementing I4.0 ecosystems. *Develop regional plans on I4.0 clusters.
Develop and attract relevant players and strategic investment	Attract investment of leading companies in I4.0 and related products. *Develop IT companies specialized in Advanced Manufacturing solutions and applications.

6. Certified Skills

DRIVERS	STRATEGIC ACTIONS
Promote career development and knowledge transfer	- Develop a specialized talent management program. -Promote a scholarship program for certified training
Implement a program to specialize professors	-Develop a national educational program aligned with demands.
Define a catalogue of industrial needs to guide academic curriculum	-Identify training and education needs. -Categorize international certifications on I4.0

7. Investment in Innovation

DRIVERS	STRATEGIC ACTIONS
Create awareness about the benefits of intellectual property	-Use the existing resources to understand actual enviro nment in order to develop the tools needed to create an efficient inte llectual prop framework.
Promote investment in innovation	- Encourage the use of existing incentives and mechanisms to increase investments in innovation companies and projects - Promote the creation of high skilled jobs
Promote innovation	*Linking research centers, universities, and industry wi th the purpose to create innovation networks specialized in ITC and I4.0

CRAFTING THE FUTURE

A ROADMAP FOR INDUSTRY 4.0 IN MEXICO

SE
SECRETARÍA DE ECONOMÍA

PROSOFT 3.0

PROMÉXICO Trade and Investment

IMS

Amiti Mejores empresas de TI para México

CLUSTER INSTITUTE