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Artículos Científicos

Impacto de la tecnología en la generación de la industria 4.0 en las pymes: estudio diagnóstico en empresas de la Ciudad de Puebla

Impact of technology on the generation of Industry 4.0 in SMEs: Diagnostic study in companies of the City of Puebla

Impacto da tecnologia na geração da indústria 4.0 nas PMEs: estudo diagnóstico em empresas da cidade de Puebla

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Resumen

La creciente tendencia en innovación tecnológica, la implementación de nuevos modelos de manufactura y la generación de técnicas de producción eficientes han provocado que se incluya en el siglo XXI el término *industria 4.0*, aspecto clave en las pymes mexicanas, las cuales representan el 98 % de unidades económicas. En esta investigación, por tanto, se analizó la influencia de la tecnología —específicamente del internet de las cosas, la inteligencia artificial y los gemelos digitales— en las pymes establecidas en el municipio de Puebla (México) con el objetivo de determinar el alcance que estos elementos tienen en los rubros de competitividad e implementación. Para ello, se utilizó un diseño de investigación no experimental transversal, ya que ninguna de las variables se manipuló y se midieron en un único momento.

El estudio tuvo un nivel correlacional que asoció las variables *industria 4.0* y *tecnología*, y tuvo un carácter explicativo porque presentó un entendimiento sobre el fenómeno examinado. Dentro de los principales hallazgos se detectó que la tecnología tiene una influencia relevante en la generación de la industria 4.0, en específico en los aspectos de las condiciones operativas, que comprenden infraestructura tecnológica y aplicación e

implementación de tecnologías inteligentes. En cambio, las técnicas avanzadas de producción tienen limitada influencia en el mencionado concepto, pues solo se implementan en los procesos de transformación de insumos en productos terminados.

Palabras clave: industria 4.0, tecnología, pymes.

Abstract

The growing trend in technological innovation, the implementation of new manufacturing models and the generation of efficient production techniques have caused the term Industry 4.0 to be included in the 21st century, a key aspect in Mexican SMEs that represent 98% of economic units, if they want to increase their competitiveness and productivity. In this research, the influence of technology was analyzed, under the headings of the internet of things, artificial intelligence and digital twins, in the generation of Industry 4.0 in SMEs established in the municipality of Puebla, with the objective of determining the scope that these elements have in the areas of competitiveness and implementation. A cross-sectional non-experimental research design was used since none of the variables were manipulated during the study and they were measured at a single moment.

It had a correlational level that associated the Industry 4.0 and technology variables, and it had an explanatory character because it presented an understanding of the phenomenon studied. Among the main findings, it was detected that technology has a relevant influence on the generation of Industry 4.0, in aspects of the operating conditions that include technological infrastructure and the application and implementation of intelligent technologies. While advanced production techniques have limited influence on the aforementioned concept, in the sense that it is only implemented in the use of technology in the processes of transforming inputs into finished products.

Keywords: Industry 4.0, Technology, SMEs.

Resumo

A tendência crescente na inovação tecnológica, a implementação de novos modelos de fabricação e a geração de técnicas de produção eficientes levaram à inclusão do termo indústria 4.0 no século XXI, um aspecto fundamental nas PMEs mexicanas, que representam 98% das unidades econômicas. Nesta pesquisa, portanto, a influência da tecnologia - especificamente a Internet das Coisas, a inteligência artificial e os gêmeos digitais - foi analisada nas PMEs estabelecidas no município de Puebla (México) com o objetivo de



determinar o alcance que esses elementos têm nas áreas de competitividade e implementação. Para isso, foi utilizado um desenho de pesquisa transversal não experimental, uma vez que nenhuma das variáveis foi manipulada e elas foram medidas em um único momento.

O estudo teve um nível de correlação que associou as variáveis indústria 4.0 e tecnologia, e teve caráter explicativo porque apresentou uma compreensão do fenômeno examinado. Entre os principais achados, detectou-se que a tecnologia tem influência relevante na geração da indústria 4.0, especificamente nos aspectos das condições de operação, que incluem infraestrutura tecnológica e aplicação e implementação de tecnologias inteligentes. Por outro lado, técnicas avançadas de produção têm influência limitada sobre o referido conceito, uma vez que são implementadas apenas nos processos de transformação de insumos em produtos acabados.

Palavras-chave: indústria 4.0, tecnologia, PMEs.

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Introduction

Currently, SMEs constitute the most important economic entities in Mexico, since they represent 98% of business units and 75% of the national economy (National Institute of Statistics, Geography and Information Technology [INEGI], 2018). However, it is important to mention that the companies in this stratum are facing a challenge of permanence in the market, since there is little investment in technology and few programs that support its development, which generally focus on generating resources to continue producing. (INEGI, 2018). This has caused not only that many SMEs close after an average period of 7.7 years (INEGI, 2020), but also that businessmen worry about the growing competition and the procedures imposed for exports, factors that are limiting constant growth. . In this context, a key aspect has to do with what is called revolution 4.0, a term that involves the inclusion of technology in the productive processes of companies, as well as in those of an administrative nature.

Industry or revolution 4.0 allows increasing the level of productivity, since it makes it easier for organizations to work with highly effective and efficient processes, as well as generate information that serves as the basis for decision-making (García, 2020). For this reason, some contemporary authors have pointed out that many businessmen are focusing on aspects related to efficiency and innovation (Ciprés, October 1, 2020; León, 2010; León-Pérez, 2019). In this same sense, some researchers explain that the subsistence of an SME in

the market depends on good management and leadership, while others refer to technological infrastructures to make them more competitive and even expand them internationally.

Based on the above, it can be stated that digital technologies are changing the manufacturing models and structures of companies, as well as those related to consumption, communication and interaction between customers and manufacturers. For this reason, it is essential to work on strategies that make it possible to determine if SMEs can incorporate industry or revolution 4.0 in their daily processes and activities. (Habib Mireles, 2022).

In this regard, it should be noted that although the systematization of control processes and the collection of information have been key factors for companies to be more effective and efficient, not all of them have the economic resources to invest in technology, which slows down their growth. development in the short term.

However, regarding the conceptualization of industry 4.0, terms such as disruptive technologies, big data, internet of things and artificial intelligence emerge, which are not limited to a single sector, but rather expand and can be used as strategic elements. to drive accelerated and exponential growth, and to reduce those elements that could cause losses for a company.

With this study, therefore, we seek to demonstrate that technology has always played an important role for organizations, but when it is not used correctly it tends to cause errors and trigger situations that can affect not only the company, but also the employees. customers.

Therefore, this paper describes the general situation of SMEs located in the municipality of Puebla (Mexico) in terms of the elements that promote the integration of industry 4.0 to their processes, since this variable is vital to ensure permanence, consolidation and development of any company.

Background

The adoption of technology has been a determining factor for the evolution of companies. However, it must be underlined that most of the employees have seen in it a potential competitor that can replace them in the short term, hence they oppose its use. In other words, it is unknown that these tools can be used to make their processes more efficient and productive, and to collect more information that allows and facilitates decision-making (Erbes et al., 2019).

Indeed, the industry or revolution 4.0 can be very useful to make tasks more secure and highly efficient in terms of data handling, which can promote user confidence.

Previously, Mexican SMEs concentrated their information physically and there was little exchange between their functional areas (Pineda de Alcázar, 2018), which limited the development of strategies and the improvement of processes. In addition to this, the collaborators had data based practically on experience and daily practice (Barleta et al., 2019), which represented a large area of opportunity to attract increasingly effective human capital and generate better results.

However, organizations that have seen technology and industry 4.0 as allies in their growth have achieved a greater position in the market and better control of their operations, which is reflected in their leadership in the sector of their competition. and in its growth and economic positioning (Erbes *et al.*, 2019).

Problem Statement

Mexican SMEs are immersed in a series of paradigms that prevent their growth and development in the short term, among which we can mention cultural, legal, sustainable aspects and even ignorance of the benefits that technology can bring to their processes (INEGI, 2018). This has caused these types of companies to present serious problems that slow down their development, such as high macroeconomic instability, scarcity of financial resources, difficulty in accessing credit, deficiencies in human capital, lack of access to technology and bureaucratic processes. Therefore, it is necessary to work on models and structures that allow reaching a higher level of competitiveness through the implementation of technology, the analysis of daily information and decision making (Barleta, 2019).

In addition to the above, it should be noted that resistance to change is another element that slows down the development of companies. This aspect is directly related to the human factor, since emerging work methods tend to be seen as a threat because they can displace labor. However, it is the job of senior management to explain how these elements can benefit all internal operations of the company.

On the other hand, and although it is true that few SMEs have the possibility of allocating resources for technological investment (Aguilera and Riascos, 2016), it is necessary to identify those key elements that they have, as well as those points of resistance for which they cannot that change has been achieved. For this, it must be insisted that certain companies cannot be fully operated with technology. In addition, it should be explained that the countries that have implemented this type of technology have achieved greater expansion and efficiency in their goods and services.

Research question

To solve the research problem, the following question has been raised:

- How does the implementation and use of technology impact the industry 4.0 generation of SMEs in the municipality of Puebla?

Secondary questions

- How does the implementation of technology in machines and equipment influence the advanced production techniques of SMEs in the municipality of Puebla?
- How do smart technologies intervene in increasing the productivity of SMEs in the municipality of Puebla?
 - How does technology intervene in improving the operating conditions of SMEs in the municipality of Puebla?

General objective

- Determine the impact of the implementation and use of technology in the generation of industry 4.0 of SMEs in the municipality of Puebla.

Specific objectives

- Identify the influence of the implementation of technology in machines and equipment in the advanced production techniques of SMEs in the municipality of Puebla.
- Relate the use of smart technologies with the increase in productivity of SMEs in the municipality of Puebla.
 - Associate the influence of technology in the operating conditions of SMEs in the municipality of Puebla.

Justification

Due to the fourth industrial revolution, there has been a great scope and speed in the growth of Mexican companies, especially the largest ones, which have been able to count on the infrastructure, technology and resources to invest in elements that enhance their productive capacities. For example, as a result of the emergence of ICTs in the first decade of this century, there was an impact of 0.6% in terms of annual labor productivity (Centro Interdisciplinario de Estudios en Ciencia, Tecnología e Innovación [CIECTI], 2019). This

has represented an exponential growth in the last two decades, which has been reflected in obtaining new clients nationally and internationally.

However, the promotion of SMEs is still pending to enhance their production processes and to identify the way in which they are using technology, an essential aspect to make them more competitive and to achieve greater amounts of sales that allow them to expand regionally and nationally.

The foregoing is in accordance with the 2017 data from the Organization for Economic Cooperation and Development, where it is shown that companies that rely on technology to measure and control their processes have 13% more productivity compared to those that rely on technology to measure and control their processes. they do not carry out this type of activity (INEGI, 2015a). Therefore, it can be affirmed that this is an area of opportunity for SMEs in Mexico, especially for those that belong to the manufacturing sector, which have greater possibilities of using big data to obtain important and impactful results.

Contextual framework

The municipality of Puebla (Mexico), where the present study is carried out, has 1,576,259 people, of which 47.4% are men and 52.6% are women, with a male-female ratio of 90.01 (Zelada, 2020). The economic participation rate of the municipality is 53.45%, with the participation of 69.09% in men and 39.79% in women.

The employed population with an income level of two or less minimum wages represents 33.84%, which represents the population with a lower income level and extreme poverty. Puebla ranks 27 out of 32 in the human development index in Mexico, and although it has been the entity with the highest growth with 3.7% in 2020, its result is still below the national average, which corresponds to 0.746 (Zelada, 2020).

The INEGI (2018) indicates that the municipality contributed 3.2% of the GDP of manufacturing industries in Mexico and employed 1,072,000 in the country. Likewise, it occupies the tenth position among the most important manufacturing economic activities in 2019.

However, in the case of the resources and capacities that Mexican SMEs have, it can be said that they are affected by the shortage of managerial skills, as well as by insufficient education and training in terms of personnel labor. In addition, the little implementation of the best quality practices, the elements of lean manufacturing and the aspects related to continuous improvement cause these organizations to have a low and variable performance

in terms of their profitability, subsistence in the market and growth. Indeed, when SMEs are unable to take advantage of the above points in an effective and functional way, they tend to stagnate in terms of their growth and development.

In the case of Mexico, SMEs represent 98% of the economic units, so their impact is reflected in the gross domestic product (Aguilera and Riascos, 2016). Specifically, these companies have the following distribution: 18.8% manufacturing companies, 10.1% wholesale trade organizations, 10.1% retail trade, 9.3% real estate services, 7.3% construction, and the rest are sectors such as transportation, mining, educational and health services (INEGI, 2020). These companies, however, have the problem of remaining in the market for a short time due to aspects related to administrative management, leadership, continuous improvement approach, teamwork, use of resources, among others.

These factors, however, can be worked through the implementation of technology, which in recent years has represented an element of competitiveness due to the type of information it provides companies for decision making. Indeed, when an organization manages to implement a technological system such as an enterprise resource program (ERP) or some other type of ICT for the management and control of its information, decision-making is facilitated. However, it is important to note that Mexican SMEs have limited resources, which prevents them from investing in this type of element. For this reason, currently many continue to work with traditional information gathering models (pencil and paper), which, although functional, represent a delay with respect to companies from other nations.

In addition to the above, it should be noted that many companies are more concerned with aspects related to distribution channels, logistics and increased productivity than with others associated with research and efficient use of information. For example, small companies carry out weak activities in terms of environmental analysis; In addition, the technology they implement is usually obsolete, which leaves them at a precarious level of competitiveness.

On the other hand, medium-sized companies have a slightly more accelerated behavior, since they carry out activities in a methodical way through the analysis of the environment, the acquisition of technology according to their needs, and the implementation of this to obtain better results (León -Perez, 2019). However, production demands can cause that even when all these elements are available, it remains in a standby process due to carelessness or mismanagement regarding the use of these technologies or due to the lack of interpretation of the information.



For all of the above, the task of being able to lead SMEs to the integration of industry 4.0 is a decision that is the responsibility of the organization as a whole, since—as has been indicated— cultural aspects and resistance to change can lead to that this process of transformation and improvement remains only a good attempt.

According to INEGI (2018), in Mexico only 15% of SMEs established in the national territory invest in technology, while the rest work with processes transmitted from generation to generation that have been in the market for up to 80 years. Although these have managed to satisfy the demand of their markets, they are also representing a focus of attention to be able to promote them, since the needs of their clients are increasing and in some cases, they are changing.

At present, the appearance of digital businesses has favored that the needs of customers are met more effectively and quickly, hence the insistence on disruptive solutions based on data and on platforms that collect information in a matter of minutes, strategies that unfortunately Only large companies from Mexico or abroad are implementing it, which has generated an abysmal technological and productive gap.

Conceptual framework

Industry 4.0

The industry 4.0 concept refers to the integration of digital elements in real time in suppliers, producers and customers throughout the supply and value chain (Barleta et al., 2019) that can be used in different phases of the operation. of an organization with the aim of making processes more efficient and controlled. This term was coined by the German initiative as a strategy that involves technology in the industrial sector and digitization in manufacturing processes (Pineda de Alcázar, 2018). It is associated with the fourth industrial revolution, where there is control of the value chain through the product life cycle.

The development of industry 4.0 is mainly driven by three phenomena (Carrasco, 2006):

Digitization and integration of both horizontal and vertical value chains.

Digitization of products and services.

The emergence of digital businesses.

Although there is no specific definition of the technologies that are involved in industry 4.0, most contemporary authors and associates in this conceptual type identify that the main ones are advanced production techniques, intelligent technologies and the operating conditions of the industry company (Barleta *et al.*, 2019).

Advanced production techniques

These are defined as the process to ensure that all activities enable the company to use technology and obtain new products and even different services from those currently delivered to the market. Within this framework, terms such as advanced manufacturing emerge, which includes developments in manufacturing that have been implemented since the end of the 20th century with the aim of carrying out increasingly intensive processes and products and supported by ICT, modeling elements and simulation. in their designs. Therefore, it involves the use of advanced production techniques that provide fewer errors, as well as saving resources (Barrantes et al., 2013).

Advanced manufacturing, as well as advanced production techniques, have a transversal nature, since most of the economic sectors use inputs or raw materials for their manufacture, for which their final products must have a high content of design. In this context, a complex technological area is necessary, since it will allow the use of high-performance technologies for modeling, analysis simulation and prototyping techniques that allow functional products to be achieved with a lower economic investment.

Smart technologies

Adapting technology in the industry is a complex process that requires not only investment, but also an organizational structure that is capable of making changes with respect to its application. In the case of intelligent technologies, these have promoted a structural change in the productive and social aspects, since currently many of the processes that are developed are controlled by software or highly configured equipment that leads to more accurate measurements.

Indeed, intelligent technologies are driving changes in all industrial sectors through high-speed data transmission networks, information storage, e-business, e-commerce and, in general, the systematization of all their productive operations. and administrative. This is causing the breaking of traditional barriers and paradigms in terms of the way of doing business and manufacturing products.

For this reason, some strategies that companies must implement to get the most out of smart technologies are mentioned below (Pimentel, 2020):

Achieve a technological position with respect to the competition, since it is important to carry out a benchmarking exercise and know the technology that can be used in the company's daily processes and operations.

Achieve progress in the areas of research and development, since in this way there will be a competitive advantage over other companies in the same sector.

It is important that the technology acquired has a specific purpose. In other words, it makes no sense to implement the most advanced technology on the market if information is not going to be collected to help the company make decisions and correctly manage its processes.

Carry out flexible processes. This element will bring an important advantage for companies, since it will be possible to serve a greater number of markets, which will facilitate the opening for new negotiations in the national and international environment. In short, technology plays an important role in driving these changes in a simpler way, which at the same time will allow diversifying processes.

Improve the organization. This factor must be restructured through the implementation of technological elements that lead organizations to develop operations immediately that involve better information gathering. In this way, you can avoid spending time capturing, retrieving, and storing data.

Investment in training. It is key when you want to use advanced technologies, since collaborators will have the skills to operate all the equipment, which will increase work performance.

Company operating conditions

From the context of the human factor of companies, the conditions under which they operate represent one of the most important points for the implementation of technologies and the generation of industry 4.0. In this sense, strategic planning and an organizational philosophy should be mentioned as the first element. These should promote the use of technology as a key factor to achieve the goals in the medium and long term, since when this factor is lacking it is very difficult to reach an optimal result of comprehensive benefit.

As a second element, the organizational culture must be considered, since the environment plays a significant role in the behavior of collaborators and the way in which they are added to meet the objectives of the company. An important analogy is the one that occurs in the companies of the European Union versus the Mexican companies, in which the ways of thinking, the social aspects and the economic indicators influence the way in which the company and the collaborators develop in their activities (Erbes et al., 2019).

Finally, the infrastructure that the company has to implement the technology must be considered, as well as those adaptation elements that allow its functionality in an optimal and comprehensive way. Unfortunately, few SMEs manage to meet this factor due to their limited resources.

Technology

It is a process of executing business activities that can be developed internally in a more efficient way to benefit third parties (customers), since it allows the development of new products and services (Madakam et al., 2015). In order to establish the use of technology as a key element of the strategy of SMEs, structured planning is required that contributes to decision-making, otherwise it can generate losses and difficulty positioning in the national and international market.

For this research, within the technology variable, concepts such as the Internet of Things, artificial intelligence and digital twins will be considered, which are defined below.

Internet of things

The Internet of Things concept is related to the ease of connecting all types of devices to the Internet, including machines and tools. This element, therefore, refers to the development of applications that allow easy handling of the processes and tools used in an industrial context (Zanella et al., 2014). Therefore, it can be defined as a network system made up of objects that have the ability to communicate and process information in a matter of seconds. It includes platforms that allow the collection, analysis, communication and exchange of information related to processes, products and services that are developed in an industrial environment. All this happens intelligently, automatically and in real time, which adds value to production, since it allows the identification of failures or anomalies.

The Internet of Things makes it possible to automate activities without —or very minimal— human intervention, which improves the quality and uniformity of products. In addition, it achieves greater efficiency and resource savings in terms of raw materials and labor through a structured failure identification program.

Artificial intelligence

Artificial intelligence is a field of computer science that is dedicated to solving cognitive problems associated with human intelligence. This concept is developed through computer systems, which depend on the availability of data and algorithms that allow establishing processes through the intervention of technology (Openshaw and Openshaw, 1997).

Artificial intelligence evolves rapidly and is influenced in part by electronics, hence a broader definition contemplates it as the science and engineering of making machines that have human-like intelligence. For this, certain programs try to understand, infer, learn and obtain results with respect to a particular situation or a process within the industrial field.

The main elements of artificial intelligence are robotics, artificial life, artificial neural networks, machine language, natural language, systems, perception and knowledge. These factors influence in a comprehensive way to understand and interpret any process, and yield results regarding its behavior, which can avoid errors and reduce labor intervention.

Digital twins

The term digital twins is associated with a software technology that helps to digitally represent the physical reality in which a business or company operates (Alfonso, July 3, 2018), either through each of its processes, obtaining of the final product or interaction of activities. For this, it uses technological resources such as big data, the internet of things, artificial intelligence and machine learning with the aim of having tools that lead to decision-making and that are complemented by factors such as simulation and prediction. . A digital twin, in other words, consists of the creation of a virtual replica in the image and likeness of a company's tangible product or process, to which certain variables such as manufacturing time and quantities are linked. All this implies the implementation of sensors and other technological resources that allow validating whether these elements are complying with those parameters defined in an integral way between clients and the company, or that are established in a regulatory manner.

After the information is collected, the digital twins rely on artificial intelligence and the cloud to generate a digital representation of the process, which makes it easier to detect errors and correct them immediately without the need to use material or human resources.

In addition to this, digital twins are also used to check if a product meets the design specifications, that is, to identify its stability and intuition, monitor some failures through

simulations, detect areas for improvement and promote preventive maintenance, reduce time of inactivity and, finally, create a unique product for each process developed.

Method

The present investigation on the generation of industry 4.0 in SMEs in the municipality of Puebla (Mexico) was based on a non-experimental design, since none of the variables was manipulated; In addition, it was cross-sectional, since the measurements of the variables were carried out in a single moment.

According to the type of level of the investigation, it was correlational, since it associates the variables of industry 4.0 and the implementation and use of technology. Likewise, it had an explanatory nature, since it offered information to understand the phenomenon studied, as well as the way in which one variable influences the other and the type of relationship between them.

Likewise, it had a mixed approach, since data collection was contemplated with quantitative and qualitative measurements of the variables studied: industry 4.0 and technology.

On the other hand, the investigation was carried out contemplating as objects of study five companies located in the municipality of Puebla, which have the following characteristics (INEGI, 2015b):

Same number of employees. Small companies have from 11 to 50 employees and medium-sized companies from 50 to 100.

Similar hierarchical structure.

Similar areas or departments.

They are located in industrial areas of the municipality.

The population contemplated was 261 elements of companies in the manufacturing sector, which are currently working in the five companies established in the municipality of Puebla.

The following formula was used to calculate the sample:

As:

$n = \text{Sample size} = ?$

$N = \text{Population size} = 261$

$Z = \text{Confidence level} = 95\% = 1.96$

$p = \text{Probability of success} = 50\%$

$q = \text{Probability of failure} = 50\%$

d = Margin of error = 5%

Once the sample was determined, which corresponds to 169 subjects, a sampling was carried out, which consists of the selection of a set of elements with particular characteristics that belong to a certain group in order to observe, study and gather information. The type of sampling used was random probabilistic, since it contemplated elements depending on the same probability of choice.

To collect the data, a questionnaire was used that was applied both online and in person to the operational personnel of the organizations studied. This included questions related to industry 4.0 and technology. The items were coded through a 5-level Likert scale (Münch & Ángeles, 1990).

Once the questionnaire was generated, it was validated by experts to determine the probability of error in its configuration. Then, a pilot test was carried out with the study subjects, the results were analyzed, the pertinent adjustments were made and their application was carried out.

The reliability of the instrument was determined through the internal consistency method based on Cronbach's alpha, which allows estimating its reliability through a set of items that measure the same construct or theoretical dimension. For this, the statistical software SPSS (Statistical Package for the Social Sciences) was used, which yielded a result of 0.985, which—according to George and Mallery (2003)—is excellent.

The instrument that contemplated the Industry 4.0 variable is presented in Table 1 according to the following dimensions and items:

Table 1. Dimensions and items of the industry 4.0 variable

Dimension	Ítem
Advanced production techniques	1. In my work area, technological models of process management have been implemented.
	2. I have the necessary technological factors to measure and control the operational processes.
	3. The correct working relationships are established between the implemented technology and the human capacities of the personnel to operate them.
	4. The company has the necessary technological elements to constantly innovate.
	5. The technology implemented in the company is used to the maximum, seeking total productivity.
	6. The necessary training is received to correctly operate both administrative and operational business activities, specifically those that involve the use of technology.
	7. The techniques used in the operational processes add value for the product and customers.
Smart technologies	1. I have identified the integration of intelligent technologies in the administrative and operational processes of the different areas of the company.
	2. I believe that the implementation of intelligent technologies has reduced errors in the productive parts.
	3. I am aware that the entity is carrying out the development of strategies that will allow the integration of intelligent technologies for the benefit of customers.
	4. The intelligent technologies implemented in the company contribute to the achievement of objectives and goals.
	5. I consider that the intelligent technologies implemented in the company are a competitive advantage compared to other companies of the same type.
	6. I understand the way my work area operates and the importance of implementing and using smart technologies.
	7. I consider that the use of intelligent technologies has favored the diversification of products.
	8. I consider that the intelligent technologies that the company has are enough to satisfy the demand of the clients.
	9. I believe that the company has successfully managed the use of smart technologies to promote widespread growth in all its operations.
Company conditions	1. Digital transformation will allow the company to obtain better results.
	2. I consider that one of the most important factors in change management is technological innovation and implementation.
	3. I believe that change management contemplates a more modern and inclusive methodology.
	4. I believe it is important that the company adopt new technologies in its operation as soon as possible.

	5. I consider it important that the company works on the interconnectivity of its operations with customers.
	6. It is important that at work there is interconnectivity in all the internal operations of the company.
	7. I believe that the conditions of the company imply a change in the ways of working with the use of new technologies.
	8. I believe that the company has the conditions to adopt the new ways of working based on the new digital trends.
	9. Digital work is ingrained in all the work I do.
	10. The work carried out with the support of technology is an important factor in obtaining better results together in the company.
	11. I am able to adapt to new trends and technological tools that are generated every day.
	12. I consider myself capable of leaving my comfort zone to experience new work environments.
	13. I am capable of continuous learning to always be up to date with new knowledge.
	14. I prefer to communicate with my co-workers in person over any other method.
	15. The company is digitally ready to contribute to the technological transformation of the country and be a benchmark in its business.

Source: self made

On the other hand, the technology variable was studied based on the dimensions and items presented in Table 2:

Table 2. Dimensions and items of the technology variable

Internet of things	1. By using the Internet I am able to obtain useful information related to my work.
	2. The company's website posts important information related to my work.
	3. Consider that the digital transformation is changing my work processes for the better.
	4. I believe that the Internet of Things contributes to my way of working.
	5. I constantly train with courses that are related to the use of the Internet for the performance of my work.
	6. The internet connection at my work maintains good connectivity, which allows me to perform adequately.
	7. Decision-making in my work depends on the information generated through the use of the Internet.
	8. Considers that the internet of things is a priority technological pillar for the entity to implement industry 4.0.

	9. Considers the continuous flow of information through interconnectivity (internet) between devices, equipment, machines and/or tools adequate.
Artificial intelligence	1. I consider that the company has the necessary digital software to guarantee the quality of the products.
	2. The computer systems that the company has are efficient and effective for the generation of products.
	3. I consider that the systems implemented in the company allow the identification of errors and correct them immediately.
	4. The use of artificial intelligence has considerably reduced errors in different areas of the company.
	5. I believe that the company has made adequate use of artificial intelligence for decision making.
	6. I believe that the company and its collaborators have been able to adapt to the implementation and use of artificial intelligence.
	7. I believe that the use of artificial intelligence has displaced the workforce in the different areas of the company.
	8. I believe that the software and systems implemented in the company have been the most appropriate and functional for the activities and processes that it develops.
	9. I believe that the company should work on the implementation of increasingly robust and functional artificial intelligence.
	10. I consider that the artificial intelligence developed so far is insufficient to meet the needs of the company.
Digital twins	1. I believe that the company has an efficient structure for safeguarding the information generated in the productive and administrative processes.
	2. The systems integrated to the productive factors have allowed the detection of anomalies in the processes or products.
	3. The use of digital twins has facilitated the development of operations by reducing time.
	4. Do you consider that the use of digital twins represents a key factor for identifying areas for improvement.
	5. I believe that the use of digital twins has made it possible to standardize operations and processes.
	6. I believe that the company has generated a correct and comprehensive association between digital twins, the internet of things and big data.
	7. The company has taken advantage of the information generated by digital twins to predict future behavior.
	8. I believe that the use of digital twins has led to decision-making that has favored the company in general.
	9. The use of digital twins has allowed the detection of failures, promoting preventive rather than corrective maintenance.

Source: self made

Results

Derived from the application of the instrument and the statistical analysis of the information provided by the study subjects, it can be indicated that —regarding the dimensions considered for the industry 4.0 variable— advanced production techniques, intelligent technologies and the conditions of the company are those that have the greatest weight and relationship with the dimensions of the technology variable. This information is useful for SME entrepreneurs, who must guarantee operational conditions to implement smart technologies, which can increase their productivity and competitiveness. This, of course, requires elements related to the infrastructure and the establishment of tools, machines and equipment that, supported by operating and digital systems, contribute to better control and development of activities.

On the other hand, within the dimensions considered in the technology variable — that is, the Internet of Things, artificial intelligence and digital twins—, the one that presents the greatest correlation with the dimensions of the first variable is artificial intelligence, followed by of the internet of things. In other words, the situation and conditions of Mexican SMEs to achieve the implementation and application of Industry 4.0 will be directly related and will be influenced by technology from the perspective of the availability and use of artificial intelligence, as well as the internet of things. In this regard, it is necessary to point out that the relevance of artificial intelligence lies in providing a prompt response to problematic situations based on previously collected information through computer systems, and that through algorithms provide the best solution to certain situations.

In this sense, one of the most important points that SMEs must work on is the collection of information about their processes, since this will be the basis for using artificial intelligence and favoring decision-making. In addition, in this area, the Internet of Things becomes important, since the distribution of information within companies through their computer systems is necessary to establish an adequate implementation of elements related to Industry 4.0.

Discussion

Derived from the results obtained, there is a similarity with what was stated by García (2020) in his document regarding the challenges of SMEs in the context of industry 4.0, where he establishes that the profile of a small or medium-sized company cannot compete with that of a large one to use the elements of the 4.0 revolution and reach high levels of



competitiveness. Among the main differences, the referred author highlights the way in which the business is managed, the assignment of roles in the personnel, the way in which it adapts to the markets and changing trends. Furthermore, regarding the implementation of technology, SMEs only rely on an approximation and knowledge, but not on an application.

In addition, it is important to highlight that one of the key factors that García (2020) exposes in the use of industry 4.0 lies in the technical and professional skills of the workers, since ICT, the internet of things and digital twins must be employed by skilled labor. This, however, seems to be an aspect to work on, since —according to this research— there is technology that is acquired, but it is not complemented with advanced production techniques to achieve high levels of competitiveness. In other words, there are key elements for improving the operating conditions of SMEs, but unfortunately they are not enhanced due to lack of training and professionalization of activities specific to each position, which also represents one of the key areas of opportunity to improve in the face of competition trends and current globalization.

For their part, Mejía et al. (2020) state that one of the most important factors for the implementation of industry 4.0 in SMEs lies in intelligent technologies and their correct use, but that cannot be achieved quickly or in a current trend in this type of organization due to the conditions experienced by companies. This is corroborated by the results obtained in this research regarding the limitations of economic resources and access to cutting-edge technology. The authors, in fact, also agree that training is a determinant in the use of ICT, as well as the factor of unemployment.

Finally, a study by Habib Mireles (2022) integrates a key element for the management of industry 4.0 of SMEs, since it focuses on the identification of knowledge and techniques that engineers must know during their professional training to implement them in their lives. quickly, which can increase the productivity of companies. This is associated with smart technologies as a notable element of the industry 4.0 variable of this research and the technology variable as a determining aspect of implementation. Even though it is necessary to deepen educational and training aspects in Mexico from the aforementioned edges, it is also advisable to promote strategies associated with the training and competence of the current collaborators of the companies to achieve adaptation to these new emerging models.

Conclusions

With what was collected in this research, it can be concluded that technology has a relevant influence on the generation of industry 4.0 of companies in the municipality of Puebla (Mexico), mainly in aspects of their operating conditions, that is, technological infrastructure and implementation of smart technologies. Advanced production techniques have limited influence in the generation of industry 4.0 in the sense that it is only implemented in the use of technology in the processes of transforming inputs into finished products.

On the other hand, artificial intelligence continues to be one of the key elements that relates technology to Industry 4.0, followed by the Internet of Things, which allows SMEs to have a different approach to competitiveness due to new trends in the global market. . This constitutes a determinant in the continuity of the business and even in the expansion of its products to international markets.

In short, it can be affirmed that the research question is answered and the general objective is achieved, since it was evidenced that the impact of the implementation and use of technology in the generation of industry 4.0 lies in the acquisition of technological elements that help to the use of artificial intelligence as a competitive factor in the detection and solution of particular problems. This, logically, must be after a collection and safeguarding of the information of the different processes with the aim of applying the Internet of Things in a comprehensive manner within the SMEs and with external agents such as suppliers and customers.

On the other hand, regarding the first specific objective, it can be indicated that it was achieved, in the sense that the technology in machines and equipment promotes the implementation of advanced production techniques. In addition, it is highlighted that the study subjects consider that to achieve this purpose they must have efficient training on the way in which the machines, equipment and software used in the management of their activities operate.

In this regard, it should be noted that the relationship between smart technologies and increased productivity focuses on using the former to its full potential. This requires the interconnection of the digital elements of the company, such as databases and historical information, to identify reference values that can be used as parameters and indicators that will serve to set goals in the short, medium and long term. This was visible in the installed

and used capacity in the productive area of the SMEs studied, hence it can be indicated that the second specific objective was achieved.

Finally, technology from artificial intelligence, the internet of things and digital twins directly influences the improvement of the operating conditions of SMEs, which makes them more profitable. However, the aspect that represents a greater challenge in its implementation are digital twins due to the high-tech aspects that they require, and that most SMEs cannot acquire, thus establishing the scope of the last specific objective.

Future lines of research

You can work on the lines of research related to digital twins and the way they are implemented in organizations; likewise, the use of artificial intelligence and smart technologies in Mexican companies, as well as their benefits and, in general, how industry 4.0 will be the new operating model for companies globally.

On the other hand, studies can be developed based on the other aspects that industry or revolution 4.0 includes, that is, cyber-physical systems, Internet of services and smart factory, not considered in this study, but that could establish a joint relationship that can determine which ones can be implemented in Mexican SMEs; In addition, develop strategies to achieve those more complex.

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