Available online at www.sciencedirect.com

ScienceDirect

Procedia Computer Science 180 (2021) 639–648

Procedia Computer Science

www.elsevier.com/locate/procedia

International Conference on Industry 4.0 and Smart Manufacturing

Evaluation of Information and Communication Technologies towards Industry 4.0

Alicia Mon , Horacio René Del Giorgio*

Universidad Nacional de La Matanza, Florencio Varela 1903, (1754) San Justo, Buenos Aires, Argentina

Abstract

The development of Industry 4.0 generates an important effect on production systems, especially on levels of competitiveness and on the integration of value chains. The speed of this transformation takes various forms depending on the branches of industrial production, impacts on SMEs and large companies differently and, at the same time, deepens the development gap in the different regions of the global productive world.

In order to detect which are the central aspects of the fourth industrial revolution, this article introduces a model created by the authors, which allows the evaluation of the level of technological development that the manufacturing industry is adopting nowadays in Argentina.

From evaluating existing ICTs in the local industry, it is possible to detect the needs for product development, adoption and innovation and their integration in value chains.

Keywords: ICTs Index; Technological Development; Industrial Development; Industry 4.0

1. Introduction

Industry 4.0 requires the horizontal integration of collaborative networks [1] in which processes are led by workers who maintain communication with multiple areas of the plant, facilitating other processes such as routes, freight flows, delivery and distribution, decreasing costs while the complexity of the products and processes increases driven by the set of technologies that are implemented [2].

The processes of industrial transformation, collaborative work, and the interdisciplinary training of workers in the organization constitute a necessary condition of adaptation to reach to achievable production plans. Although digital

* Corresponding author. Tel.: +54-911-59696940 fax: +54-11-44808900.
E-mail address: hdelgiorgio@unlam.edu.ar

10.1016/j.procs.2021.01.286

transformation is oriented to the use of specific technologies, it is inherent the combination of human capacity with the ease that allows the use of machines and in general of technological elements, requiring a plurality of competencies of the professionals that contribute in the use of massive information, specialized machines, customer service and sagacity to generate immediate solutions in all aspects [3].

In a dichotomous way, Industry 4.0 requires professionals to respond with multiple tasks to suit the needs of the industry, but it also opens the option for new professions that are framed in specific tasks, such as content creators, creators of applications or software specialists, among other specialties [1].

Industry 4.0 represents the end-to-end integration of the value chain that goes from changes in the demands of the public to achieving satisfaction by smart factories [4]. Faced with this great transformation, the current Industry in Latin American countries needs urgent technological changes, given that the competitiveness of companies involves globalization, productivity, innovation, and the incorporation of technology as a pillar of development [5].

In order to detect which are the central aspects of the development of ICTs in Industry 4.0 of the context in Latin America, a measurement instrument has been developed to evaluate the specific characteristics of Software, Hardware and Infrastructure products that may define with precision the attributes of Industries 4.0 of the latest works found in Argentina. Although the new tools, technologies, materials, methodologies, energy sources and all the factors that fall under the name of Industry 4.0 constitute the essential levers to achieve it, there has not been found in the current bibliography the analysis of the adequate products that are implemented in specific companies and how each of these elements impact on the levels of productivity, or the interaction between them.

It is for this reason that the ICT evaluation model created by the authors [6], the methodological aspects designed to validate the model and obtain the index and the results obtained from its application in the manufacturing industry of La Matanza, are set out below. La Matanza is the district with the highest industrial production in the Province of Buenos Aires, in Argentina.

2. Materials and Methods

2.1. Model Structure

The proposed model is structured based on the detection of technological products in Industries, differentiated into 3 ICT components: Software, Hardware and Infrastructure.

These 3 components have been identified through a distinction that has been validated with experts [7], and that groups the products according to the specificities of each type of technology.

The developed model proposes a cross between the identified typologies of ICTs with the functional areas within the industries, where these technologies fulfill the different functions in the areas where they are implemented, in order to be able to accurately detect the specific products that are used for the proper performance of production processes in different areas.

Once these technological products and their intersection with each industrial process have been identified, the model proposes an assessment by levels according to:

- Their degree of development in terms of the time they exist as tools used in the market
- If the type of support they provide contributes with information that is sensitive to companies
- The complexity of the problem they solve
- If their use impacts on an improvement of processes or on the control of processes
- If it improves efficiency in the use of resources
- If it improves productivity in processes
- If it reduces operating costs
- The degree of innovation generated by its implementation and application in the field of industry

In this way, 3 current product levels are established, depending on whether they are Basic technology, Medium technology, or more Advanced technology, aimed at the transformation of Industry 4.0. This qualification has been instrumented from a double entry table, where the specific products corresponding to each group of ICTs in the

types of Software, Hardware, or Infrastructure with the functional areas of the Industry are crossed. Then, a weight is assigned to each crossing according to the current level of each identified product.

The following categorization results from this scale according to the weighting for each ICT product:

- Basic: with value 1
- Medium: with value 5
- Advanced: with value 10

The Figure 1 shows the Matrix Table of the model, which defines the crossings to determine the relationship between ICTs and Industrial Processes and indicates the valuation defined for each specific product. The rows represent each specific ICT product, grouped by type and sub-type according to the classification within each grouping. The columns represent the identified process areas in which the products fulfill a certain function.

The sum of the values of each intersection within the same weight allows establishing a score and a range for each technology category. Given that there are 120 ICT values identified at the intersection with production processes and the weight of this value category is 1, the sum of these elements yields a result of 120 points for the Basic level.

Similarly, there are 119 ICT values identified for the Medium level at the intersection with production processes, and the weight of this value category being 5, the sum of these weighted elements yields a result of 595 points.

Finally, there are 66 ICT values identified at the intersection with production processes for the Advanced level and, being the weight of this value category 10, the sum of these elements yields a result of 660 points.

The valuations that arise from the sum of the index weight are shown in the Table 1, where each valuation of the level (Basic, Medium, Advanced) is represented in the *Total Amount of Items* column, and the sum for each category is represented in the column *Summation of the Values*. Along with this value, the summation accumulated between one category and the others of a lower level is shown in brackets.

Table 1. Amount and Sums of each Valuation.

Valuation	Total Amount of Items	Summation of the Values
Basic (1)	120	120 (120)
Medium (5)	119	595 (715)
Advanced (10)	66	660 (1375)

The results of the index calculation establish ranges according to the minimum and maximum values for each category. Thus, the Basic level category of ICTs is defined in a range of 0 to 120 points, the Medium level category of ICTs is defined in a range of 121 to 715 points, while the Advanced level category of ICTs is defined in a range of 716 to 1375 points.

	INDUSTRIAL PROCESSES → / ICTs↓	Management	Finnance and Accounting	Engineering	Purchases	Logistics	Production	Sales
SOFTWARE	WEB Technologies - WEB Page (External Site)	1						1
	WEB Technologies - Intranet (Internal Site)	1	1	1	1	1	1	1
	WEB Technologies - Extranet (Transactional)				5	5		5
	WEB Technologies - Online Advertising	5						5
	Collaborative Systems - Video Conference	10		10				10
	Collaborative Systems - IP Telephony	5	5	5	5	5	5	5
	Collaborative Systems - Instant Messaging	1	1	1	1	1	1	1
	Collaborative Systems - Email	1	1	1	1	1	1	1
	Collaborative Systems - Social Networks	1						1
	Collaborative Systems - File Synchronization	5	5	5		5	5	5
	Collaborative Systems - Mobile Applications	5	5	5	5	5	5	5
	Office Tools - Word Processor	1	1	1	1	1	1	1
	Office Tools - Spreadsheet	1	1	1	1	1	1	1
	Office Tools - Presentations	1	1	1				1
	Office Tools - Database Manager		5	5	5	5	5	5
	Office Tools - Calendar and Email Manager	1	1	1	1	1	1	1
	Office Tools - PDF File Manager	5	5	5				5
	Office Tools - PDF File Reader	1	1	1	1	1	1	1
	Management Systems - Enterprise Resource Planning	5	5	5	5	5	5	5
	Management Systems - Customer Relationship Management	5	5					5
	Management Systems - Customer Claims Support							5
	Management Systems - Dashboard / Balanced Score Card	10						10
	Management Systems - Business Intelligence	10	10	10	10	10	10	10
	Management Systems - Big Data	10	10	10	10	10	10	10
	Management Systems - Machine Learning	10		10			10	
	Management Systems - Energy Control Software			10			10	
	Management Systems - Logistics / Supply			5	5	5	5	
	Management Systems - Quality Management System	5	5	5	5	5	5	5
	Management Systems - HR Management	5	5					
	Production Control Systems - Programming and Planning			10			10	
	Production Control Systems - Product Data Management			10			10	
	Production Control Systems - Product Quality						5	
	Production Control Systems - Plant Engineering / Maintenance			5			5	
	Production Control Systems - Automation Control			10			10	
	Production Control Systems - SCADA Systems			10			10	
	Production Control Systems - Embedded Systems			10			10	
	Product and Process Design - Computer Aided Design			5				
	Product and Process Design - Computer Aided Manufacturing						10	
	Product and Process Design - Computer Aided Engineering			10				
	Product and Process Design - Augmented Reality			10			10	
	Product and Process Design - Virtual Reality			10			10	
	Geolocation Systems - Distribution and Logistics					5		
	Geolocation Systems - Advertising							10
	Security Systems - Critical Infrastructure Security	5	5	5	5	5	5	5
	Security Systems - Critical Information Security	5	5	5	5	5	5	5
HARDWARE	Computers - Desktop PCs	1	1	1	1	1	1	1
	Computers - RISC Architectures			5			5	
	Computers - Notebooks	1	1	1	1	1	1	1
	Computers - Tablets	1		1		1	1	1
	Printers - Laser Printers	1	1	1	1	1	1	1
	Printers - 3D Printers			10			10	
	Printers - Scanners	5	5	5	5	5	5	5
	Printers - Plotters			10			10	
	Point Of Sale (POS)							5
	Shared Disks	10	10	10	10	10	10	10
	Programmable Logic Controllers						5	
	Global Positioning System					5		
	RFID Devices					5		
	Telephone exchanges - Traditional telephone exchanges	1	1	1	1	1	1	1
	Telephone exchanges - IP telephone exchanges	10	10	10	10	10	10	10
	Sensors					10	10	
	Robots					10	10	
INFRASTRUCTURE	Wireless Convergent Networks - Mobile Telephony	1	1	1	1	1	1	1
	Wireless Convergent Networks - Wi-Fi Networks	1	1	1	1	1	1	1
	Wireless Convergent Networks - Bluetooth Networks	5	5	5	5	5	5	5
	Wireless Convergent Networks - Internet of Things Networks			10		10	10	
	Local Servers	5	5	5	5	5	5	5
	Cloud Computing	5	5	5	5	5	5	5
	Wired Local Area Networks	1	1	1	1	1	1	1
	IT Security	5	5	5	5	5	5	5
	Internet connection	1	1	1	1	1	1	1
	Closed Circuit Television					1	1	

Fig. 1. Cross between ICTs and Industrial Processes.

These results of the index calculation can be seen in the Table 2, where the ranges for each category are exposed. The *Range* column shows the maximum and minimum values of the sum of the weighted values for each category, while the *ICT Adoption Level* column shows the level of each of the three categories mentioned above.

Table 2. Range and ICT Adoption Level.

Range	ICT Adoption Level
Between 0 and 120	Basic
Between 121 and 715	Medium
Between 716 and 1375	Advanced

To apply the developed model, a set of survey instruments has been created. They allow to identify, in each Industry, which are the specific products that are implemented to fulfill their functions.

2.2. Research Method

To apply the model, a set of methodological instruments were designed that allow the survey to be carried out in specific industries.

With them, a field study was carried out to validate and adjust the index as well as to evaluate the level of technological development as a sample of the manufacturing industry in a district of the province of Buenos Aires.

- *Survey*: A structured closed questionnaire was designed, which contains questions about the ICT products installed in each company and the function they fulfill according to the functional area in which they are used.
- *Key Informant*: The profile of the key informant who must complete the survey was determined according to the necessary knowledge about the technologies implemented in the company.
- *Sample*: A probabilistic sample was designed with a margin of error of 5%, to carry out the survey on a universe of 4.000 industries located in the district of La Matanza, located in the Buenos Aires suburbs, bordering the city of Buenos Aires.
- *Field Work*: A survey was carried out in 40 industries of various branches and size.
- *Software*: An automatic evaluation Software was developed, which contains the survey in digital format, generates the calculation of the index and reports the result digitally and privately to each user who completes the questionnaire, together with their company information.
- *Database*: A database was designed to process the surveys and record the calculation of the index.
- *Website*: A website was developed from where the software is accessed for individual and private evaluation by each company.

Among the set of instruments, a survey contained in a form with empty boxes has been designed, as can be seen in the Figure 2.

	INDUSTRIAL PROCESSES → / ICTs↓	Management	Finnance and Accounting	Engineering	Purchases	Logistics	Production	Sales
SOFTWARE	WEB Technologies - WEB Page (External Site)							
	WEB Technologies - Intranet (Internal Site)							
	WEB Technologies - Extranet (Transactional)							
	WEB Technologies - Online Advertising							
	Collaborative Systems - Video Conference							
	Collaborative Systems - IP Telephony							
	Collaborative Systems - Instant Messaging							
	Collaborative Systems - Email							
	Collaborative Systems - Social Networks							
	Collaborative Systems - File Synchronization							
	Collaborative Systems - Mobile Applications							
	Office Tools - Word Processor							
	Office Tools - Spreadsheet							
	Office Tools - Presentations							
	Office Tools - Database Manager							
	Office Tools - Calendar and Email Manager							
	Office Tools - PDF File Manager							
	Office Tools - PDF File Reader							
	Management Systems - Enterprise Resource Planning							
	Management Systems - Customer Relationship Management							
	Management Systems - Customer Claims Support							
	Management Systems - Dashboard / Balanced Score Card							
	Management Systems - Business Intelligence							
	Management Systems - Big Data							
	Management Systems - Machine Learning							
	Management Systems - Energy Control Software							
	Management Systems - Logistics / Supply							
	Management Systems - Quality Management System							
	Management Systems - HR Management							
	Production Control Systems - Programming and Planning							
	Production Control Systems - Product Data Management							
	Production Control Systems - Product Quality							
	Production Control Systems - Plant Engineering / Maintenance							
	Production Control Systems - Automation Control							
	Production Control Systems - SCADA Systems							
	Production Control Systems - Embedded Systems							
	Product and Process Design - Computer Aided Design							
	Product and Process Design - Computer Aided Manufacturing							
	Product and Process Design - Computer Aided Engineering							
	Product and Process Design - Augmented Reality							
	Product and Process Design - Virtual Reality							
	Geolocation Systems - Distribution and Logistics							
	Geolocation Systems - Advertising							
	Security Systems - Critical Infrastructure Security							
	Security Systems - Critical Information Security							
HARDWARE	Computers - Desktop PCs							
	Computers - RISC Architectures							
	Computers - Notebooks							
	Computers - Tablets							
	Printers - Laser Printers							
	Printers - 3D Printers							
	Printers - Scanners							
	Printers - Plotters							
	Point Of Sale (POS)							
	Shared Disks							
	Programmable Logic Controllers							
	Global Positioning System							
	RFID Devices							
	Telephone exchanges - Traditional telephone exchanges							
	Telephone exchanges - IP telephone exchanges							
	Sensors							
	Robots							
INFRASTRUCTURE	Wireless Convergent Networks - Mobile Telephony							
	Wireless Convergent Networks - Wi-Fi Networks							
	Wireless Convergent Networks - Bluetooth Networks							
	Wireless Convergent Networks - Internet of Things Networks							
	Local Servers							
	Cloud Computing							
	Wired Local Area Networks							
	IT Security							
	Internet connection							
	Closed Circuit Television							

Fig. 2. Form to collect data from the Industry.

This Form allows calculating an individual assessment for each of the Industries. When conducting the survey with the necessary instruments, the boxes where the Industry has an ICT implemented in the corresponding process area are marked with a cross, while where there is no match, that box will be blank.

With the Industry registry, the crosses are replaced by the values of the index weight according to Figure 1, all the indicated values are added together, and the result obtained shows the value of the *ICT Adoption Level* that the Industry has according to the range exposed in Table 2: *Basic, Medium or Advanced*.

3. Results and Discussion

The field work was carried out on 40 companies in the district of La Matanza, in the Province of Buenos Aires, Argentina.

From the analysis of the survey, it can be seen that 45% of the companies are *Micro* (up to 15 employees); 25% is made up of *Small* (up to 60 employees), while in the category of *Medium Section 1 and Medium Section 2* (up to 235 and 655 employees respectively) 17,50% is located between both categories, and only 12,50% are located in the *Large* company category (more than 655 employees), as can be seen in the Figure 3.

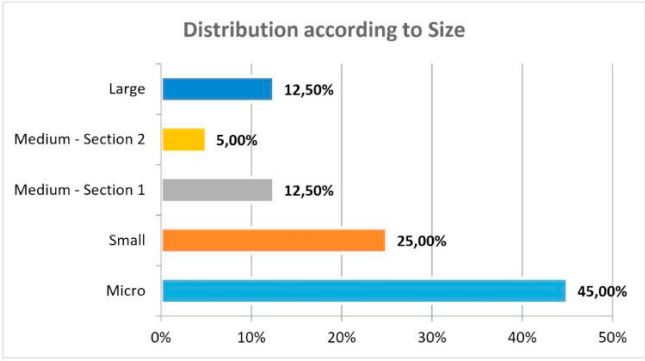

Fig. 3. Distribution according to Size.

From the analysis of the results on the ICT Adoption Level, it can be seen that, of the 40 companies surveyed, 62.50% are at the *Basic* Level, 35% at the *Medium* Level and only 2, 50% at the *Advanced* Level, as shown in the Figure 4.

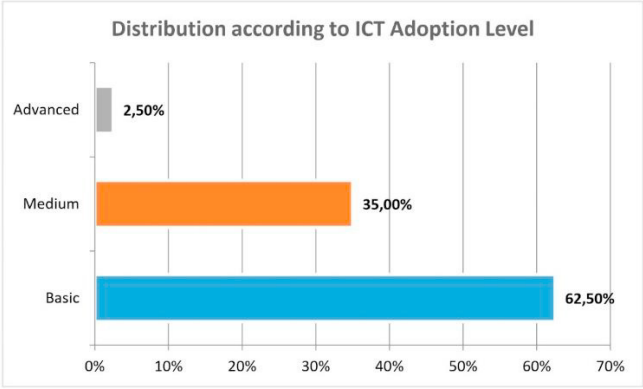

Fig. 4. Distribution according to ICT Adoption.

If the analysis by branch of activity is undertaken to compare *within a branch*, it is possible to detect the differences on the ICTs implemented, and thus the following tables show the percentages obtained at each level and type of products for 3 companies.

The Table 3 sets forth the values for a micro company in the metallurgical branch whose result of applying the ICT Adoption Level assigns a score corresponding to the Basic Level.

Table 3. Metallurgical Industry - Basic Level.

ICT	Basic	Medium	Advanced
Software	14,29%	0,00%	0,00%
Hardware	20,00%	0,00%	%
Infrastructure	0,00%	0,00%	0,00%

The Table 4 sets forth the values for a small company in the metallurgical branch whose result of applying the ICT Adoption Level assigns a score corresponding to the Medium Level.

Table 4. Metallurgical Industry - Medium Level.

ICT	Basic	Medium	Advanced
Software	42,86%	27,27%	16,67%
Hardware	40,00%	66,67%	33,33%
Infrastructure	80,00%	25,00%	0,00%

While the Table 5 shows the values for a large company in the metallurgical branch whose result of applying the ICT Adoption Level assigns a score corresponding to the Advanced Level.

Table 5. Metallurgical Industry - Advanced Level.

ICT	Basic	Medium	Advanced
Software	100,00%	90,91%	83,33%
Hardware	60,00%	100,00%	50,00%
Infrastructure	100,00%	50,00%	100,00%

Regarding the Technologies that could currently be called “essential” in a Company, one of the relevant data observed is that, of the Industries surveyed with a Basic ICT Adoption Level, a significant percentage of them (28%) do not have a WEB Page (External Site).

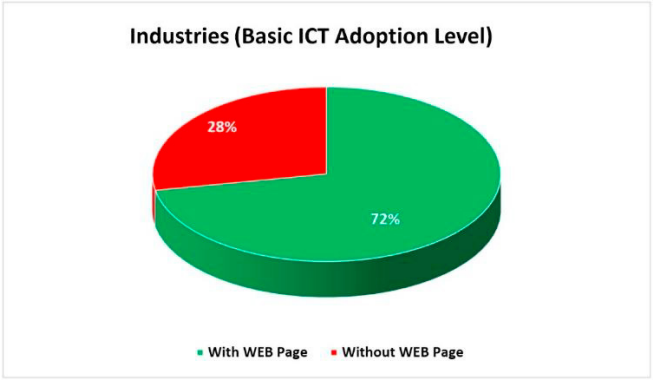

Fig. 5. WEB Page in Industries with Basic ICT Adoption Level.

While, of the industries surveyed with a Medium ICT Adoption Level, the percentage of those that do not have a WEB Page (External Site) is lower (14%), although in this case it would be expected that 100% companies with this ICT Adoption Level already had this technology deployed. It is even more significant that this small percentage is made up of Large and Medium-sized companies, which implies that there are companies that, despite having an appreciable weight in the market, do not include this type of Technology.

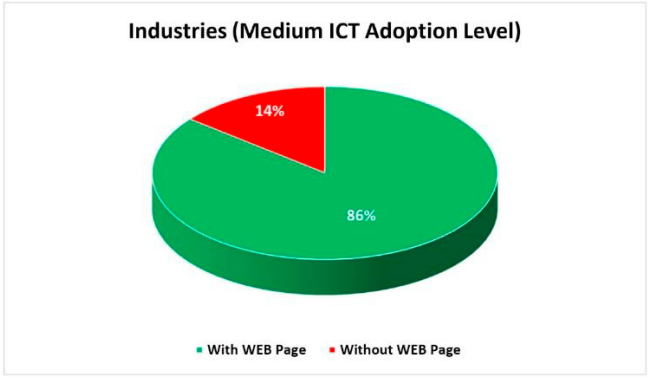

Fig. 6. WEB Page in Industries with Medium ICT Adoption Level.

On the other hand, it is remarkable that, of the industries surveyed with a *Basic* ICT Adoption Level, 60% have *at least* one component of Industry 4.0; that is, Integration Systems, Autonomous Machines and Systems, Internet of Things, Additive Manufacturing, Big Data, Cloud Computing, Simulation of Virtual Environments, Artificial Intelligence, Cybersecurity, Augmented Reality [8]. This could indicate that a certain drive is imposed towards the technological transformation of any type of Company, even with a Basic level of development, due to the simple fact of modernizing. Although in some cases it could be the lack of financial resources. Then, in many cases of personally conducted surveys it was observed that there are many companies that do not have knowledge of the ICTs' universe to which they could have access. Some of them did not even know the term "Industry 4.0".

These results represent a sample of the type of analysis that can be carried out with the instruments developed for the industry in general and within it by size of Industry, by branch of Industry, as well as by a particular Industry; and similarly, for a particular district.

4. Conclusions

In this article, an ICT evaluation model has been exposed to determine the level of technological development, differentiated as Advanced, Medium and Basic, existing in the manufacturing Industry and the results of its application in an industrial district of Argentina.

The Advanced ICT Adoption Level constitutes the base of the industries that are in the process of transformation towards Industry 4.0. However, it is necessary to differentiate between existing technologies and trends in technological development, in order to assess, in the real context of use, what are the levels of technological development, by branches of activity, according to the implementation of technologies that have been in the market for a long time, technologies that have been on the market for an average time or the latest technologies that the market registers within each of its types in order to detect implementation needs and capacities for innovation.

The model has been applied from the survey of a set of 40 Industries of various branches and size. The results show that the model created is valid for the detection of existing ICT products in manufacturing companies.

On the other hand, it is possible to identify the characteristics of the different branches and sizes of companies, in order to detect existing products and what would be the necessary technological transformation path for SMEs towards Industry 4.0. It is also possible to detect implementation needs and capabilities for innovation, without neglecting the urgent need for Human Resources training.

References

[1] Stezano, Federico. (2017). "The Role of Technology Center as Intermediary Organizations Facilitating Links for Innovation: Four Cases of Deferal Technology Centers in Mexico". Review of Policy Research, vol.1, pp.45-67.

[2] MINCyT. (2015). "Industria 4.0: Escenarios e impactos para la formulación de políticas tecnológicas en los umbrales de la Cuarta Revolución Industrial". Ed. Ministerio de Ciencia, Tecnología e Innovación Productiva.

[3] Suárez, David, Arjona, José Ángel, García, Mercedes, and García, Roberto (2016). "Qué es la Industria 4.0". Available from: http://www.ningenia.com/2016/05/31/que-es-la-industria-4-0

[4] Albrieu, Ramiro, Basco, Ana Inés, Brest López, Caterina, de Azevedo, Belisario, Peirano, Fernando, Rapetti, Martín, and Vienni, Gabriel. (2019). Travesía 4.0: hacia la transformación industrial argentina. Nota Técnica 1672. Ed Banco Interamericano de Desarrollo.

[5] Bitar, Sergio. (2020). "El futuro del trabajo en América Latina. ¿Cómo impactará la digitalización y qué hacer?". Ed Diálogo Interamericano. Available from https://www.thedialogue.org/wp-content/uploads/2020/02/Future-of-Work_Feb-2020-V-FINAL.pdf

[6] Del Giorgio, Horacio René, and Mon, Alicia. (2019). "Las TICs en las Industrias". Ed Universidad Nacional de La Matanza. Available from https://indicetics.unlam.edu.ar/it/pdf/Las_TICs_en_las_Industrias.pdf

[7] Mon, Alicia, and Del Giorgio, Horacio René. (2018). "Análisis de las Tecnologías de la Información y la Comunicación y su innovación en la industria". Libro de Actas de CACIC 2018 XXIV Congreso Argentino de Ciencias de la Computación, pp.887-895. Available from http://cacic2018.exa.unicen.edu.ar/pdf/LibroDeActasCACIC2018.pdf

[8] Basco, Ana Inés, Beliz, Gustavo, Coatz, Diego, and Garnero, Paula. (2018). "Industria 4.0: Fabricando el Futuro". Ed Banco Interamericano de Desarrollo.