Level Exploration of the Companies' Maturity in the Industry 4.0

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Abstract: ***The Industry 4.0 has brought disruptive technologies, as a result, the manufacturing context of products and services, in business, economy and the connectivity, takes the companies to adopt these technologies. This analysis explores the maturity level of companies in Puebla, Mexico, and the Industry 4.0 characteristics by a Toolbox 4.0. As a result, it indicates that the companies aren't ready to the Smart products manufacturing in cyberphysic systems since the levels of automation are incipient.***

Keywords: Industry 4.0, Maturity Level, Disruptive Technologies

1. Introduction

Now a day, the technology is a success and competitive element in business companies to local, regional, national e international level. The result brings new manufacturing process in products and services, marketing methods, working, learning, making business, taking decisions and others. The manager of XXI century should pay attention to all changes creating smart strategies to the Industry 4.0 and the Smart manufacturing organizations to get high level in productivity and competitivity in the global site. This takes us to analyze how the companies are accepting disruptive technologies of Industry 4.0 like artificial intelligence, cloud data, robotics, augmented reality, internet of things, 3d printing and others.

Problem

The objective in this study is to make a maturity level exploration in Puebla City companies, comparing the 4.0 Industry characteristics like virtual reality, digitalization of operations, robotization, cloud data, automation and others to know what action courses could be developed.

2. Literature Review

In the society, the most important is the change especially business and own life's, as well as economic, productive, educative and political models, etcetera. The industrial and technological revolutions as changes and innovation agents, have been since 1766. In the first revolution appears the productive process, vapor and mechanic systems. In 1879, in the second revolution appears the electric energy and fossil fuel and 1969, the third revolution use the alternative energies, electronic and Information technology. The last industrial revolution appears to the XXI century, beginning in Germany. This revolution was characterized for the fast changes, the technological, social and human importance besides the impacted and interconnected systems (Basilio, 2018) because the fifth revolution is coming.

At 2011 in Hannover's Fair, Germany also awards itself the 4.0 Industry concept, It was discussed how it Will be affected the global value chains through Smart factories, were the virtual and physical making systems, called cyber physical systems, helps all systems flexibility, so, one of this particularities is the convivence between all variety of convergent technologies and the limits with physic digital and biologic process that may be a little line to change the paradigm and process's transformation (Schwab, 2016).

In addition, 4.0 industry can be considered as a revolution or an evolution. If it is a revolution, it must be disruptive in the new business solutions, however, it can lead to oversizing some aspects of it. As evolution is the consequence of model's progress and the exist industrial systems (Roig, 2017). It's very important to know from the industrial revolution beginning to the strategies that the administrator XXI has to develop.

The companies that decide to continue with revolution fourth or 4.0 Industry have to plan how to develop the next elements because this is changing the actual factories in all process, (Martínez, De Juanes, Hernández, and Pérez, 2019) principally:

- Products design management and productive Systems.
- Production digitalization and the rest of life cycle.
- The industrial communications and cyber security
- New organizations and gestion models.

The future factory has selected new disruptive elements as cloud computing, big data, data mining, robot, simulation, system integration, internet of things (IoT), industrial internet of things (IIoT), Artificial intelligence (IA), cyber security, 3D press, augmented reality, as the main.

As a disruptive element of Smart factory, the cyber physical system is the existing integration and coordination with physical process and computational systems through all network components (Park, Zheng, and Liu, 2012), because it is where the vertical and horizontal integration in the value chain begin (Neri, 2019), through communication machine - machine (M2M), machine - internet, machine - person (M2P) and others, see figure 1.

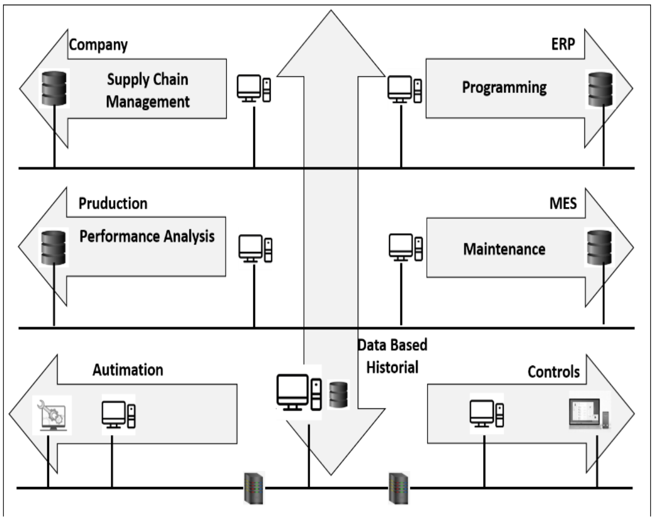

Figure 1: Horizontal and vertical Industry 4.0 integration
Source: Own elaboration adapted from MOOC Industry 4.0.

The cyber physic systems management vertical integration begins with the high direction through strategic planning with the planning of company resources. All of this is supported with supervision, control and data acquirement; from the program logics controls, the measurement and detection of machines and equipment parameters to their online monitoring constitute the productive systems vertical integration. See table 1.

The first activities are horizontal integration as operation, sales, human resource, logistic, etc. These have to coordinate in real time so that the optimization of value chain increases. In consequence, the second activity where the administrator functions as recruitment and selection personnel is included, personal hiring, payment, training, quality management systems, security and hygiene, administrative process value through administrative auditories, marketing, marketing search, etc., must be optimized and coordinated to real time to help the value chain vertical integration.

Table 1: Industry 4.0 and its value chain levels.

Level	Place	Principal Function	Information System	Typical Data	Information Processed	Operation Time
4	Plant management	ERP: planning, scheduling, materials and logistics	Database, interfaces, applications Strategic	KPIs like sales, finance	To Plan and move resources to achieve strategic objectives	Days of weeks
3	Design and production	MES: optimization and management of the entire plant	History of processes, database applications, middleware	KPIs of the operation such as production, inventories	To Optimize and execute operations throughout the plant	From minutes to hours
2	Management of production certificates	Automation, advanced control processes, management of anomalies	SCADA's, PC – based systems,	Operating objectives per unit, level 1 metrics	Units operated at their optimal point	From seconds to minutes
1	Individual machine control	Basic control, rectification, statistical analysis	PLC's, DCS, software for sensors	Variable set points, process values, alarms	To Maintain process variables at their desired values	From Milliseconds to seconds
0	Field signals	Measurement and sensing, online monitoring	Sensors, actuators and field devices	Measured values of actual process variables,	Actual flow of process values	Continuous

Source: Adaptation of the Technological Institute of Aragon - MOOC Industry 4.0.

Finally, the automotive sector is one of the principal users of 4.0Industry, so that, its strategic planning consists in change from traditional to smart factory. For example, Tesla company has a Gigafactory, in Sparks, Nevada and its characteristic are learning through "machine learning" concept and its AIV's autonomous indoor vehicles (Barros, 2017). It has been reflected in the batteries production, besides, there is already another Gigafactory in Buffalo, USA. In 2018th, in Shanghai, China, two Gigafactories more were built (Álvarez, 2018). There are others automotive sector companies that are developing technologies to 4.0 Industry as Grupo PSA, 3DEPERIENCE, Towards 5G, Audi and others (Barros, 2017)

3. Methodology

The methodology used had a qualitative focus through an explorer study or close up (Rojas, 2010, 40) with the subjective realities analysis of 4.0 Industry concepts. In this study, it has designed different evaluation models to measure the 4.0 Industry maturity in the companies. According to the purpose, they are descriptive, prescriptive and comparatives (De Carolis, Macchi, Negri and Terzi, 2017), in consequence, there arenot a recognized representative model to vale the 4.0 Industry maturity (Jacquez and López, 2018). The Toolbox tool was use to know the level to 4.0 Industry maturity in the companies (Instituto Tecnológico y de Estudios Superiores de Monterrey, 2016). This tool has a structural base (Grajales, 2018) with different criterias to value the maturity level as a reference point in a diagnostic.

The toolbox has 7 criteria to 4.0Industry: system automation level, data process in production, machine - machine communication, company - production communication channels, ICT infrastructure in production, man - machine interface and efficiency with small groups, see table 2.

Table 2: Toolbox for Industry 4.0

Criteria	Nivel				
	0	1	2	3	4
a) System automatization level	Production processes with sensors and signals with continuous measurement	Detection and manipulation with PLC and actuators with measurement in seconds	Monitoring and supervision with SCADA/ HMI with measurement in minutes	Manufacturing Execution Systems with measurement in hours	Planning of company resources measured in days
b) Data process in production	No data processing	Storage of data for documentation	Analysis of data for monitoring	Evaluation for processes of planning and control.	Automatic processes of planning and control
c) Machine - to - machine communication (M2M)	None communication	Interfaces of field buses	Interfaces Industrial Ethernet	The machines have access to internet	Web services (software of M2M)
d) Company - production communication channels.	There are no networks communication between production and the other business units	Exchange of information via email or phone	Formats uniforms of data and rules for data exchange	Formats uniforms of data and servers interconnected	Networks with IT and interdivisional
e) ICT infrastructure in production	Exchange of information via email or phone	Servers of power stations data in the production	Shared web - based portals of information	Exchange automatic gear information	Suppliers and customers are immersed in the process of design
f) Human - machine interface (M2P)	There is not exchange of information between the user and the machine	Using local user interfaces	Control of the production centralized/ decentralized	Use of interfaces mobile for the Username	Reality increased and assisted
g) Efficiency in small production groups	Rigid production systems and a small proportion of identical parts	Use of systems of production flex and parts identical	System of production flexible and designs modular for the products	Flexible production of products modular powered by the components	Production modular with value - added networks driven by the components

Source: elaboration adapted with information of "Instituto Tecnológico y de Estudios Superiores de Monterrey".

Development

28 enterprises were taken into consideration for this study, being in different areas like services, food and beverage, metal mechanic and automotive 61% were big and 36% were medium size enterprises having the following results: according to the principal components, this study reflects that the automation level criteria have 53% variability and four factors were analyzed with 88.5% of dispersion. Community values near to 1 are showed with no rotates data in the factorial analysis, and it's correct. Besides, it was realized a four factors analysis to identify no rotated and rotated dates differences between four factors selected.

Finally, the elements analysis was realized to look at thane internal consistency and the questionaries' apply according to alfa's Cronbrach criteria where 0.7 to 0.95 area considered acceptable (Barrios and Costella, 2013), the alfa value to questionnaire was 84.53% and for any element or constructor (see, table 3) are 79.62% to 85.45% of alfa's value, so the internal consistency and questionnaire confidence were valued statistically.

Table 3: Omitted Item Statistics

Omitted Variable	Adjusted Total mean	Adjusted Total Standard Deviation	Total Adjusted Correlation per Item	Square Multiple Correlation	Cronbach's Alpha
Automation	18.250	5.841	0.5147	0.5886	0.8369
Prosecution	18.500	5.815	0.7414	0.5952	0.8023
M2M	18.857	5.681	0.6917	0.5051	0.8101
Communication	18.286	5.931	0.5713	0.6077	0.8285
TIC	19.000	6.152	0.3917	0.5225	0.8545
M2P	18.857	5.823	0.7794	0.6336	0.7962
Efficiency	18.536	5.815	0.5418	0.5495	0.8329

Source: Self - made

In general, the elements correlation is positive, only exists negative relation between system automation level and Tic infrastructure in production with correlational coefficient, r, of - 0.80. in the system automation level, higher are 0.612 with data processing in productive system, with machine - machine communication was 0.505 and 0.644.

4. Results

The results obtained were showed in table 4. The system automation level is based in ANSI/ISA - 95 normative with six parts and the propose is develop automatics interfaces between company and systems control. To level four, 43% develop business resources planning with an answer in the control systems in days.0, 1 and 2 level showing the real time information in the product manufacture and 3 level is showed the production capacity information.

Table 4: Results of the Toolbox for Industry 4.0m

	Percentage				
	Level 0	Level 1	Level 2	Level 3	Level 4
System automation level	11	25	14	7	43
Data processing in the production system	4	32	21	25	18
Machine - to - machine communication (M2M)	29	4	39	11	18
Company - production communication channels	0	39	11	18	32
ICT infrastructure in production	25	18	25	25	7
Human - machine interface (P2M)	18	14	36	29	4
Efficiency in small production groups	21	11	25	14	29

Source: Self - made with Minitab

In data processing of productive system, 32% of companies save data only as a historical and 18% of companies use data to planning process and automatic control. In the machine - machine communication 39% is in level two so the communication is for industrial interfaces of ethernet, the other hand 29% doesn´t have communication between machines.

For company - production communications criteria, 39% the companies use the e - mail or via telephone to information exchange although 32% companies do it with IT networks an interdivisional. In the infrastructure of TIC in the production criteria, 25% companies use the e - mail or telephone to exchange information, 25% companies exchange information for web portals with information sharing and they are in level two and 25% companies are level three because they use the exchanging automatic information.

In the man - machine interface, the 36% represents the production control in centralized/ decentralized enterprises and 29% companies use mobile interfaces to user and production control.29% companies have a modular production value - added networks component driven, other hand, 25% companies answered to this characteristic with flexible production systems and modular design.

5. Discussion

The disruptive elements in the digital revolution search to increase the productivity and competitiveness in companies. It is necessary that companies identify strengths and weaknesses of 4.0 Industry disruptive elements. The management changes and disruptive technologies don't easily apply in companies and governments but is a way to get intelligent factories.

In this exploratory study in the 4.0 industry companies, it was analyzed the value - added in different situations through Toolbox and ANSI/ISA - 95 normative to identify the maturity level of them. The process consisted in statistics value of internal consistence between constructors and correlations, having a satisfactory result with 84.53% Cronbach alfa value. The automation level results showed that companies have to work in vertical and horizontal integration, it means that they have to work in cyber physic systems, detection and manipulation systems of success critical variables, monitoring and control the interfaces between the final product of information flow with support areas and related activities business management.

In the data processing to planning process and automatic control have to increase more because only 18% companies are in level four that is the limit to reach. To get it, it is necessary to collaborate with disruptive elements of 4.0 industry through vertical and horizontal integration of cyber physic systems that is shown in applied surveys which results are 18%, 32%, 7%, 29% and 4% of M2M communications, companies - production communications channels, infrastructure of TIC'S in the production, M2P Interphase and efficiency with small groups, respectively.

Having other sources of information regarding the appropriation of these disruptive technologies of 4.0 industry analyzed, we found that, according to an investigation by the German National Academy of Science and Technology about the concept of 4.0 Industry, the question was asked to the representatives of companies and organizations from industrialized nations (Instituto Tecnológico y de Estudios Superiores de Monterrey, 2016), the following: "What does 4.0 Industry mean to them? so they found that for 16% it means new business models; 18%, automation; 20%, production optimization; 20%, smart products and; 26%, networks and digitization".

These answers indicate that some companies have not envisioned a comprehensive change, just something isolated or a new trend that companies should consider for their competitiveness. It is necessary to develop a systemic approach to relate the disruptive elements of 4.0 industry, consequently, the vision will also be disruptive with a composition of the information of the horizontal and vertical structure of its cyber - physical systems, establishing communication channels and technology for the smart factories manufacture.

On the other hand, according to a study carried out in Mexico (Martínez, Álvarez, & García, 2020), there are key elements to consider for the adoption of the elements of 4.0 Industry, such as the digital economy and the evolution of technologies, the threat of technological unemployment, digital jobs and new policies in this new digital environment.

Firstly, as promoters of this technological and economic development, companies should begin the migration of their traditional processes to cyber - physical systems. However, their size (large, medium and small and micro companies) and sectors influenced the adoption of 4.0 technologies, the challenge is great for SMEs, given their profiles and differences with medium and large companies in terms of resources and strategic planning. The digital transformation in SMEs is a challenge that they must face together with the government at its three levels, municipal, state and federal, in addition, there are exogenous factors such as international treaties with different countries and other associations such as the World Bank, the Organization for Cooperation and Economic Development, with its policies for theeconomic development of the countries.

Secondly, the industrial sector specializes in innovation and technology, specialization and division of labor (González A., 2022), and the automotive and aerospace sectors are implementing these technologies to increase their competitiveness and productivity, as well as, continuing with B2B and B2C business. Also, it is important to know the trends of 4.0 industry (Wallner, 2022), which are: Cobots and AI in flexible production; virtual start - up to verify processes; the regulation and standardization of communication processes between machines, people and process; AI - based algorithms will dynamically optimize the production line performance; So, companies must carry out their strategic planning with a vision of these trends and technologies of 4.0 Industry, in addition, they must focus their attention in the consumers because they require a personalized and individual attention (Vallejo, 2022).

Thirdly, it is necessary for companies to implement 4.0 industry technologies, besides having entrepreneurs with a disruptive company's digital transformation vision, changing into a smart factory. However, it is not enough, having system integration knowledge, professionals in PLC SCADA are required, automation, supervision and control, experts in operations management, ERP integrations, document management or manufacturing order management, among others, are required as well as, specialists in manufacturing execution systems, MES. The application of the ANSI/ISA – 95 standards must be carried out by engineers who are knowledgeable and responsible for all technologies related to the automation and sensors of the smart factory, M2M and IIoT. Experts in Big Data, Open Source and Middleware that integrate all systems horizontally and vertically and thus form the cyber - physical system. Specialized personnel in data mining for real - time, data analysis to improve the industrial plant and business options. Cloud support is required to make connected industry possible. In addition, experts in Machine Learning are required to improve processes and carry out preventive maintenance actions or even experts in 3D printing and additive manufacturing (Digital Talent Agency, 2022).

6. Conclusion

In this study, a small group of companies has been explored to identify how they are using 4.0 Industry technologies in their systems and organizational structures. The obtained results show that the basic technologies that support the Fourth Industrial Revolution have not been developed in the same way. If we consider that smart products (del Val, 2022) are integrated with electronic components, embedded software and connectivity that together are characterized by new features and functions and are manufactured in cyber - physical systems through the Internet of Things (IoT), then most companies must consider new strategies to meet this challenge.

Cyber security is an issue that must be developed, since cyber - physical systems, machine - to - machine (M2M) communication, mobile connectivity for person - to - machine (P2M) communication, cyber - physical production systems (CCPS), the supply chain intelligent, the management of the relationship with intelligent customers, among others, require high reliability in the protection of the management of the information found in the cloud (Cloud computing) and more basic technologies that require extreme confidentiality.

This means that companies invest in their collaborators new digital skills to face this new reality, since it is required that all their information systems such as the accounting information system (AIS, Accounting Information Systems), management information system (MIS, Management Information System), decision support systems (DSS, Decision Support System) and its manufacturing planning and control system (MCP) are developed and integrated vertically and horizontally for the intelligent products manufacture.

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