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# Reengineering and Innovation to facilitate the transition from industry 3.0 to 4.0

# Reingeniería e Innovación para facilitar la transición de industria 3.0 a 4.0

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**Abstract**

Disruptive innovation project regarding technologies available in the transformation industry, in order to face the challenges of globalized competition, respond to a production logic with characteristics of the so-called smart factory and thus close the technological gap to the use contemporary and innovative industrial automation systems through cyber physical elements for the constitution of a digital twin. Among the significant tasks, the review and analysis of the integration means for Industry 4.0 was developed through the use of techniques and tools of rapid methodologies for the design and management of engineering projects, as well as the diagnosis and design proposal of solution in improvements. Therefore, it is a functional approach to the estimated interpretation of international standards when developing the application of a standard process control solution with the capacity to be reworked and composed in such a way that a hybrid productive architecture is generated.

**Industry 4.0, Evolution Industry 3.0, Industrial Project Methodology**

**Resumen**

Proyecto de innovación disruptiva en lo concerniente a tecnologías disponibles en la industria de la transformación, con la finalidad de hacer frente a los desafíos de la competencia globalizada, responder a una lógica productiva con características de la denominada fabrica inteligente y así cerrar la brecha tecnológica al utilizar sistemas contemporáneos y novedosos de automatización industrial a través de elementos ciber físicos para la constitución de un gemelo digital. Entre las tareas significativas se desarrolló la revisión y análisis de los medios de integración para industria 4.0 a través del uso de técnicas y herramientas de metodologías rápidas para el diseño y gestión de proyectos de ingeniería, así como también de la propuesta de diagnóstico y diseño de solución en mejoras. Por tanto, es una aproximación funcional a la interpretación estimada de los estándares internacionales al desarrollar la aplicación de una solución de control de procesos estándares con capacidad de ser retrabajados y compuestos de forma tal que se genera una arquitectura productiva hibrida

**Industria 4.0, Evolución Industria 3.0, Metodología de proyectos industriales**

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## Introduction

The schematization of industrial revolutions in history carried out by Ana María Reyes Fabela and Rene Pedroza Flores (1) generates a panorama of understanding of key moments and characteristics.

| Movement | Temporality | Characteristics |
|---|---|---|
| Agricultural revolution | -2500 BC | Using animal energy, simple technology |
| First Industrial Revolution | Century XVIII | Mechanical power, steam engine |
| Second Industrial Revolution | XIX century | Chain manufacturing, fast production lines |
| Third Industrial Revolution | Twentieth century | Flexible manufacturing, electronic automation |
| Fourth Industrial Revolution | Started in 2010 | Smart factories, connected industry, Industry 4.0 |

**Table 1** Industrial revolutions in history
*Source: Reyes Fabela and Pedrosa Flores (2018)*

Technological use is an indicator of vital importance to increase productivity, this in any of the tasks carried out as a species, in such a way an example can be cited in which two average people move from point "A" to point " B ", one on foot and the other by bicycle, it can be assumed that the person on a bicycle travels in less time and with less effort than the other, in such a way that by having the necessary technology the activities are facilitated and generate added value. The term industry 4.0 was coined in Germany in 2011, but conceptually they reveal a competence to jointly develop a comprehensive technological solution (Deutschland.de, 2014).

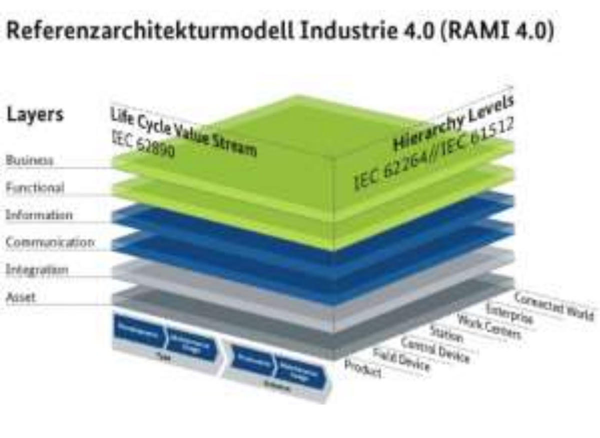


**Figure 1** Industry 4.0 architecture reference model
*Source: ZVEI (2015)*

The functional guidelines of Industry 4.0 by having a vertical axis in which the layers of representation of Information Technology are immersed; In other words, the digital image of the Business, the Functionality, the Information, the Communication, the Integration and the Assets, proposed in this way due to the complexity of their use in an IT solution, allows to identify and separate the parts of predecessor technology to facilitate migration (ZVEI, 2015). According to Siemens (2021), Industry 4.0 "It is about the union between the real and virtual world in factories, that is, the application of information technologies to production processes.

The facilities are autonomous and the production chain self-managed, which allows a more flexible configuration that provides quick and efficient responses to market demand. Likewise, all the information derived from the manufacturing process is available in real time in all the areas that make up the company. "

In Mexico, little has been invested in the migration of productive technologies, and there are few cases of success. It is automotive-type companies that have carried out some work. (El Financiero, 2019).

Currently there is a technical deficiency in the intercommunication of technologies that manufacturers and suppliers supply to the industry separately, there are both hardware and software elements, but they are not properly connected and intercommunicated with each other, such as approval, as well as use of the OPC communication protocol in its different variables.

The companies that have been organized to include analysis technologies and improvements in production processes such as HMI / SCADA manage to allocate the data obtained through field elements to automate, with which they arrive at a result of a large number of information about its processes, but a very vague reason in the analytical and intelligent processing of that information, deficient for purposes of supporting executive decisions in the company.

The diagnosis of Mexican companies in relation to the concept of Industry 4.0 through an exercise on forms and information management, refers to the following figures:

| Organization | Total | % |
|---|---|---|
| Automation | 7 | 78 |
| Brewery | 6 | 67 |
| Inlay | 6 | 67 |
| Gas | 4 | 44 |
| Messenger service | 5 | 56 |
| Metalworking | 4 | 44 |
| Mining | 6 | 67 |
| Transportation | 9 | 100 |

**Table 2** Level of competence in processes and digitization
*Source: Díaz-Martínez, Cruz Méndez and Ruiz-Domínguez (2018)*

The industrial sector is considered an engine of innovation, growth, social stability, by responding to customer demands; with products of the highest quality, personalized and with shorter production times (Díaz-Martínez, Cruz Méndez and Ruiz-Domínguez, 2018); to achieve business growth and develop sustainable competitive advantages (Porter and Kramer, 2011; Barney, Ketchen and Wright, 2011; Marvek, Davis and Sproul, 2016).

The objective of this work is to develop an analysis and transformation methodology, using devices with shapes and designs similar to those of Industry 3.0, through IOLink or OPC UA communication that are integrated and allow predictive tasks mediating analysis of variables, in a timely manner. facilitate the structuring of a strategic plant operation and maintenance plan

The importance of this research is based on the fact that there are no studies on methodologies that support the migration of industry processes 3.0 to 4.0, through the integration of a team of experts, mediating the correct adjustment between the environment and the capacities of the organizations; It starts from the cloud through control technology, IoT Gateway to sensors and actuators, which improves customer-centric decision-making, thereby boosting business innovation, by generating competitive advantages in MSMEs with significance in the economic development of the country.

Work continues with the conceptual framework, as well as a review of the literature and related empirical studies. Followed by the section that describes the methodology used, while the analysis and results are presented in a later section, to finally present and discuss the conclusions, limitations and implications for future research.

## Methodology

In order to evolve from Industry 3.0 to 4.0, technology exists in a vast variety of separate field elements that, in the first instance, are not related to each other in a practical way, which makes it difficult to choose tangible and intangible equipment, supplies, and tools. an application process integrated into an automated production line or chain.

For Michael Rüßmann, Markus Lorenz, Philipp Gerbert, Manuela Waldner, Jan Justus, Pascal Engel, and Michael Harnisch, the semantic composition in approach to the RAMI 4.0 model as a nuclear source in a multisystemic way of industrial technologies and solutions is graphically described in its approximate shape as follows:

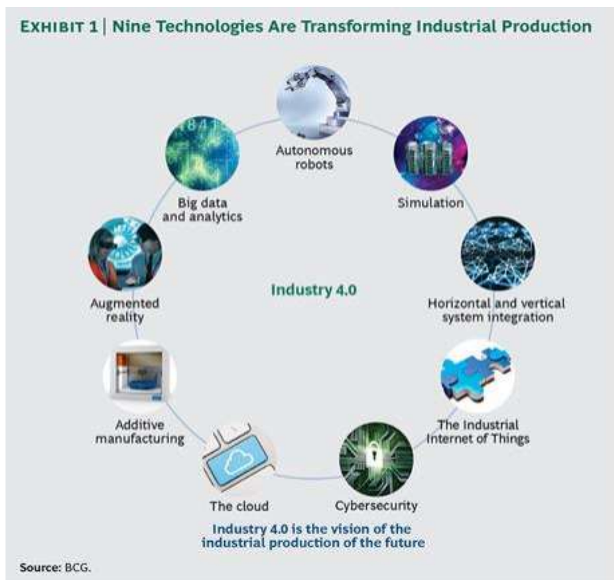


**Figure 2** The nine technologies that are transforming industrial production
*Source: Rüßmann (2015)*

Lean manufacturing "This phase involves the development of smart factories that are capable of using various digital technologies in production processes, in order to efficiently develop their products and meet market needs ... the so-called fourth industrial revolution consists of a complete digitization of a factory's supply chains by means of tools such as: data processing and analysis, software systems, sensors and process automation, through which the prediction of market factors is facilitated, as well as production planning and control, thus adding an important value to the entire chain. " (Lean manufacturing 10, n.d.)

| RAMI 4.0 Semantic Composition | General information features | ZVEI Standards Category - Norm |
|---|---|---|
| Robotic Autonomy | Programming in Codesys, Festo PLC, IFM Sensors, Danphoss Inverter, Inlet Hopper Granulator, Final Chill Roll. | Safety equipment IEC 61511, IEC62061, ISO 13849, IEC 62453 Configuration, IEC 62714 Engineering, ISO / PAS 17506, IEC 61131, IEC 62264 Hierarchy Levels |
| Simulation | Visual Studio, SQL or Oracle, Blender | Digital Factory IEC TR 62794, IEC TS 62832, IEC 62890 Life Cycle, Monitoring Conditions (CM) VDMA 24582, IEC 61131 Engineering, IEC 61987-X, IEC 61360, IEC 62264 Hierarchy Levels |
| Vertical and horizontal information systems | Configuration of the field element communication system with user visualization services | Configuration IEC 61804, IEC 62453, Life Cycle IEC 62890, CM, VDMA 24582, Hierarchy Levels IEC 62264 |
| IoT | OPC UA, iOlink, Ethernet internet connection protocol with industrial data upload and download. | Communications layer - IEC 61784, IEC 62541 OPC UA, Engineering IEC 62714, IEC 62424, DIN SPEC 16592 |
| Cybersecurity | Microtik or Check-Point for brute force, Social engineering prevention course, | Computer security IEC 62443, ISO IEC 27000, Security equipment IEC 62061 and 61511, Hierarchy Levels IEC 62264 |
| Cloud | Microsoft Azure, Customer-tailored plant design application, Visual Studio C #, PHP Maker | Life Cycle IEC 62890, CM, VDMA 24582, Information Layer eCl @ ss (ISO 13584-42 / IEC 61360) Hierarchy Levels IEC 61512 and 62264, Semantics RIF / SRWL, UWL, RDF (S), SPARQL |
| Additive Manufacturing | ERP design by Oracle or SQL by means of a Supply Chain Equation | Configuration IEC 61804, IEC 62453, Energy Efficiency ISO 20140-5 |
| Augmented reality | Oculus, Unity, Blender, Database connectivity (SQL Oracle), Systems: training and maintenance. | Life Cycle IEC 62890, Monitoring Conditions (CM) VDMA 24582, |
| Analytics in Big Data | Statistical Queries, Production Metrics, R, R +, SQL Oracle | IEC 62890 Life Cycle, VDMA 24582 Monitoring Conditions, IEC 62714, 61360 and 61987-X Engineering, eCl @ ss Information Layer (ISO 13584-42 / IEC 61360), IEC 62264 Hierarchy Levels |
| Robotic Autonomy | Programming in Codesys, Festo PLC, IFM Sensors, Danphoss Inverter, Inlet Hopper Granulator, Final Chill Roll. | Safety equipment IEC 61511, IEC62061, ISO 13849, IEC 62453 Configuration, IEC 62714 Engineering, ISO / PAS 17506, IEC 61131, IEC 62264 Hierarchy Levels |

**Table 3** Information extracted from the EDT dictionary according to the migration project
*Source: i40-semantic-Interoperability (2017)*

Engineering FEED or FEL (Front-End Engineering Design - Front End Loading) consisting of elaborating the basic parameters of the process, determining the arrangement and sizing of equipment and ideal models, designing and specifying the systems in their constitution in this case of hardware for production and processing of industrial control and sales channel software for them, as well as the necessary equipment to achieve the assurance of productive technologies, thus establishing the specification of their benefits and work performance in an ideal industrial environment (Davon and Jablokow, 2015)

For the programming of the device, users must use the Codesys software package version V3pbF, which allows the editing of code by structured text as well as by the simplified introduction of data, list of instructions, ladder diagram, function block diagrams, diagram of sequential function blocks, simplified fieldbus configuration, elements for connection via IOLink protocol, loading of controllers or various sensor libraries with preloaded internet of things characteristics, management of search for errors in programming, standard of 10/100 Mbit / s communication via Ethernet, Modbus TCP client server, easy IP protocol as well as TCP / IP and connectivity service via OPC, function library for autonomous function according to IEC 61131-3 standard (CODESYS, 2019) . Regulations related to RAMI 4.0, in which the general and specific characteristics of a development in Industry 4.0 are cataloged, to give light to the technology migration methodology.

The control system of a device that allows adjustments of a signal in a closed link, is achieved by permuting the same signal, by managing the action of a proportional, integral and derivative signal.

Proportional control action, precise minimization of the error in the system, before a prominent error the control action is of the same category in order to generate a tendency to decrease the error, the response speed of the system is increased, the Steady-state system error increases system instability.

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Derivative control action, the derivative of the error is understood as the speed of the error, when the measurable variable moves at a high speed towards the reference point, the controller must recognize the speed of the system in order to decrease its speed in anticipation of the approach. in the reference to avoid startles, the stability of the controlled system increases, the system error rate is minimally decreased, the steady-state error remains the same, this control action serves to stabilize the response outside the upper or lower ranges.

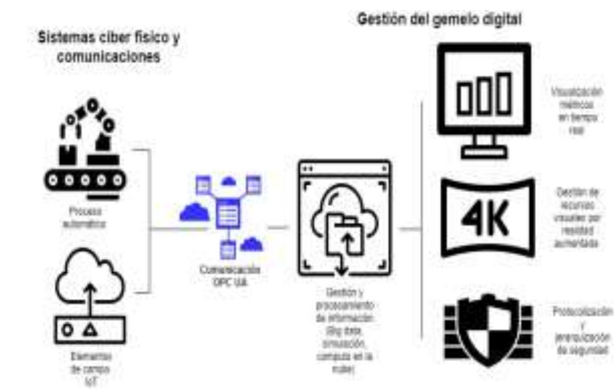


**Figure 3** aphic model of elements worked for the development of the migration methodology

Integral control action, calculates the integral of the error signal, which can be observed as the sum or accumulation of the error signal that over time the integration is greater, which allows the reduction of error in the system, Steady-state system error is decreased, system instability increases, system speed is minimally increased.

To specify the function in a real product, it is necessary to program a function whose equation allows closed-loop control work.

$$c(t) = Kp \cdot e(t) + Ki \cdot \int e(t)dt + Kd \cdot \frac{\delta e(t)}{\delta t} \tag{1}$$

Where:

$c(t) = control\ signal$
$e\ (t) = \ error\ signal$
$Kp, Ki, Kd\ =\ PID\ controller\ parameters$

In real control systems there are certain limitations that reduce the ability to control the error to reach the desired response since, no matter how much the proportional action increases, the actuator field element would be overloaded with events to control the variable in error, therefore If it depends on the response speed, they have limits that cannot be overcome even for the current control.

After carrying out the PID control system and communication system according to the OPC UA protocol, the indicator display system is modeled, using the software development kit that Visual Basic introduces.

Through Microsoft Azure, it is configured as a PC stored on the internet, which in turn stores a relational and incremental database with which information from field elements such as sensors and actuators is managed. The variable display system adheres to the design as executable and portable on a web platform.

The team with programmable characteristics develops the functions of network manager of the solution by integrating the various equipment with appropriate IoT work characteristics, as well as the respective structured cabling network with industrial category. (Mikrotik-Mexico, 2017)

## Results

A value proposition and key differentiators in a company that integrates innovative technologies requires the acquisition of licenses for its own developments, for an exercise of innovation and / or undertakings in accordance with the new market needs, in that of analysis, as well as information management productive of a portfolio of clients with a close relationship and enough communication allows a contractual technical solution, as well as executable.

The management of an evolutionary migration methodology from industry 3.0 to 4.0 is supported in a versatile way through the tools of project development techniques by agile methodologies. The acquisition, storage, visualization and management of information by protocols of automatic characteristics significantly reduce the time of managerial decision due to the utilities or applications that displace the preparation of reports by a version of indicators that can be modeled in real time and ubiquity.

The Industry 4.0 solution is obviously a sum of technological elements of various kinds, which makes it a complex multisystemic plot, based on the robust OPC UA communication protocol between composition applications, it must favor self-diagnosis in order to avoid failures hard on the system.

For integration work according to RAMI 4.0 standards for Big Data Analysis solutions, Vertical or Horizontal Integration Systems, Cloud Computing, Cybersecurity, Robotic Autonomy, Industrial IoT, Simulation and Augmented Reality. There is a sufficient and at the same time growing catalog to achieve quality work in Industry 4.0.

Among the most anticipated products due to their ability to interact is the integration of augmented reality elements as they favor divergence in what is commonly known as industrial professional life, and contextualize the user of the productive hardware in a significant change in the performance of job functions

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**Conclusions**

Due to the magnitude of technological integration that includes industry 4.0, mainly from the growth of the internet and utilities based on the solution of various problems from computer science, which has promoted immediate effects both in the productive organization, and impacting in global market competition.

The development of a methodology, the conceptual support of a series of protocols, processes and measures to be executed for the migration from Industry 3.0 to 4.0, whose progress metric transcended in the integration of a group of experts, as well as in the strategic execution of a multisystemic project, this evolution dissolves modern technological approaches and creates expectations for new reaches in the transformation industry based on the normative standards of RAMI 4.0.

The optimization of performance in organizations is explained through the ability of the company to constantly renew itself, by managing to identify and exploit new opportunities, in response to customer demands and continuous improvement, now through the simulation of the behavior of productive teams through virtual reality, as well as augmented reality for the rapid diagnosis of failures in productive systems.

On the other hand, through the web services of the system database, shared conditioning resources for the calculation of machine decision intelligence and the distribution of important information, based on weekly, monthly, annual histories with followers of significant events. and specific reports.

From this exploratory exercise, lines of research and development of complementary, auxiliary, peripheral, or related technologies that will help in the emergence of business models or rapid undertakings are perceived.

The present study is not without limitations, the complete coverage of all the articles that deal with the topic of Transition from industry 3.0 to 4.0 could not have been achieved, given the chosen search procedure. Therefore, there could have been works that having been directed to automated systems, a different language was used. Consequently, the factors derived from the analysis need to be treated with caution.

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