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Janus Methodology: Integrated automation in industry 4.0, an approach for the digital transformation of enterprise

Metodología Janus: Automatización integrada en industria 4.0, un enfoque para la transformación digital de empresas

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Resumen

La instauración-aplicación del enfoque de Industria 4.0 (I4.0), tanto en nuevas empresas como en las ya establecidas, requieren, entender el enfoque, donde la tecnología es consecuencia de aplicar los preceptos y conceptos del enfoque que dan el indicativo de que se debe mejorar en los procesos. En I4.0, los cambios están dados "No en lo que se hace sino en cómo se hace", buscando la personalización de productos en masa por medio de procedimientos ágiles y procesos configurables, y realizando mejoras sucesivas hacia una empresa verde. En este trabajo mostramos una metodología que permita bajo el enfoque de I4.0 realizar las proyecciones respectivas sobre el proceso productivo (empresa), estableciendo la brecha entre el estado actual de la empresa y lo deseado con I4.0, generando un diagnóstico para establecer una ruta admisible de implantación. El diseño de la metodología es basado en la automatización integrada de procesos de producción desde la óptica de Unidad Holónica de producción que contiene el enfoque de I4.0.

Palabras clave: Industria 4.0, Metodología para la automatización, Transformación Digital, Mejoramiento Continuo, Automatización Integrada..

Abstract

The establishment-application of the Industry 4.0 approach (I4.0), both in new and established enterprises, requires on their part, an understanding of this approach, where technology is a consequence of applying the precepts and concepts of ths approach that gives an indication of what should be improved in the processes. In I4.0, the changes are given "Not on what is done but on how is done", searching the customization of mass products through agile procedures and configurable processes and making successive improvements towards a green enterprise. In this work we show a methodology that allows, under the I4.0 approach, to make the respective mapping on the production process (enterprise), establishing the gap between the current state of the company and what is desired with I4.0, generating a diagnosis to establish an acceptable path of implementation. The design of the methodology is based on the integrated automation of production processes from the perspective of the Holonic Unit of production that contains the I4.0 approach

Key words: Industry 4.0, Methodology for Automation, Digital Transformation, Continuous Improvement, Integrated Automation..

1 Introduction

The fourth industrial revolution, known as Industry 4.0 in Germany, Smart Factory in the US or simply I4.0, is the evolution of a precept for the integral and integrated automation of the industry, initiated in the third industrial revolution, which uses-requires new methods and methodologies, and new techniques and technologies for its application. This relatively new approach, associated with the customization of mass production products, consists of an integrity of technologies, organizational concepts and management principles that underlie a profitable, responsive, resilient and sustainable production network (ecologically and financially), based in data, dynamically and structurally adaptable to changes in supply and demand through rapid reorganization and reallocation of its components and capabilities. As it can be noted, there are many aspects to consider in I4.0; Although it is true that there is already a Reference Architecture Model for I4.0, RAMI 4.0, (Schweichhart 2016, Plattform Industrie 4.0 2018) developed by the German Association of Manufacturers of Electrical and Electronic Products (ZVEI), see Fig. 1, which shows a three-dimensional map approach to the deployment of Industry 4.0 in a structured way, its aim is to ensure that all participants involved in Industry 4.0 discussions and activities have a common framework for understanding each other. RAMI 4.0 allows the identification of standards to determine if there is any need for additions and amendments. As suggested by Lydon 2019 the RAMI 4.0 reference model is generally applicable and can be used to derive specific models.

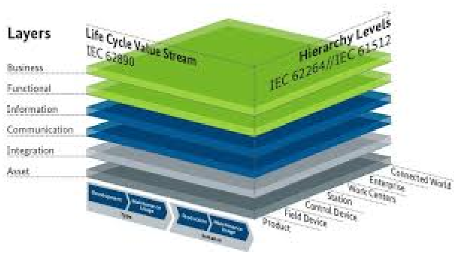

Fig. 1: RAMI 4.0,

Due to the complexity of addressing all aspects indicated for establishing the I4.0 approach, in this work we show a methodology that allows, progressively, the achievement of the features of I4.0 in a company. The methodology is the compendium of experiences obtained in the integration of processes and then the implementation of into a viable path to implement I4.0.

While it is true, it cannot be established that all companies must be I3.0 as a premise to move towards 4.0. The methodology can be used to make improvements in the company both in business processes and in production, which leads to the application of the I4.0 approach and therefore make a continuous improvement of the company that guides it to go towards I4 .0. To do this, in section 2 we show the requirements to consider to establish the I4.0 approach, and the impact of digital transformation on the adaptation process. Section 3 shows the fundamental aspects considered for the development of the methodology. Section 4 shows the Janus Methodology and the steps to apply it. In section 5 a discussion and finally the conclusions are shown.

2 Industry 4.0 and Digital Transformation

The passage from stage 3 to Industry 4.0 is due to a change in the manufacturing and production concepts that motivate the incorporation of enabling techniques and technologies to these digital changes. We talk about the motivators and enablers of I4.0.

2.1 Industry 4.0 (I4.0)

Industry 4.0 is an integrity of technologies, organizational concepts and management principles, that underlie a profitable, responsive, resilient, sustainable and ecological production network, based on data, dynamically and structurally adaptable to changes in supply and demand through rapid reorganization and reallocation of its components and capabilities.

When we talk about I4.0, most of the arguments are associated with the technological aspects and pillars. According to Rüßmann et al. 2015 the main aspects are: Big Data and Data Analytics, Cloud Computing, Cybersecurity, Internet of Things (IoT), Process Integration, Advanced Robotics and Artificial Intelligence, Vertical and Horizontal Integration Systems, Hyperconnectivity, Digital Manufacturing, Manufacturing Execution Systems, and Virtual Augmented Reality. But in essence, Industry 4.0 is a paradigm that uses new technologies to manufacture, measure, transport, and provide information on physical objects. From the Holonic approach (Chacón et al. 2021). Resources make decisions autonomously, cooperate to achieve common objectives, so they are considered cognitive entities, which have the ability to make predictions. These capabilities in the processes allow the "***Customization of Products***" that were mass-produced, for great flexibility to establish configurations and reconfigurations online, thanks to its high level of automation, this being a main feature of Cyber-Physical Systems.

A precondition for I4.0 is to have automated processes, however, what is being automated? How can we evaluate that automation is complete? What is correctly and consistently established? Automation is defined as "the use of machines and computers that can operate without the need of human control", according to ISA-88 1995 it is defined as "the creation and application of technology to monitor and control the manufacturing and delivery of products and services". In our case we assume an alternative definition such as "the programming of procedures (skills-competences) in entities (resources) that fulfill an end, for the accomplishment of the manufacturing process". These entities interact to obtain a product according to the instantiation of the product route over the asset hierarchy. This assignment has always been done, what has changed is the way to do it, this aspect is its evolution. Thus, at each stage of the industrial evolution we will have our own methods, methodologies, techniques and technology.

The viability of production is established through a negotiated goal according to the capacity, ability-competence of the entities involved and to the "physical-logical" connectivity that they have with other entities. A premise for a correct automation is the systematization of the processes, which is particular to each production process, which provides all the required information. Considering this we can say that:

- For manufacturing processes, it is required to verify-establish the routes for the production (of batches) of products according to the configurations of the cells, and production units and lines, established in the asset hierarchy, according to the availability of equipment, raw materials and supplies, associated with production planning.
- For continuous production processes, it is required to verify-establish a permanent flow of product over (very long) periods of time. Here the configurations are associated with the set points in the equipment governed by the sequence of operations to process the product flow in each stage of the process according to the conditions of the same (quality, quantity). That includes the transients of the beginning and end of the supply of the product flow as well as its variations in the respective periods of time.

From the perspective of I4.0, having custom products implies:

- Knowing:
  - The status of the resources according to the asset hierarchy.
  - The status of the product or product flow.
  - The status of production orders.
- Having:
  - Agile planning, is having full knowledge of the process and enough automation to establish schedules (equipment), reserves (raw materials and supplies), and configurations (route) in the manufacturing process in a flexible way.
  - Execution on time without waste: it means having full knowledge of the coordination-supervision schemes (routes, configurations) for normal conditions, anomalies, failures, contingencies. As well as full knowledge of control and regulation schemes in equipment.
  - Monitoring: of the product and the process, is to define, establish, and obtain indicators in the product, processes, carbon trace, energy consumption (of what type).
- Being an smart company: is having the ability to make predictions (in every sense).

Two key elements of how a company wants to evolve towards I4.0 is through motivators and enablers. Motivators come from the need to be competitive and customer-centric. It seeks to have: a) Short periods in product development, b) Product adaptation to customers, c) Flexible production, d) Autonomy, and e) Efficient use of resources, (Chacón Ramírez et al. 2020).. The enablers are: a) New technologies and automation on the floor, b) Networks and Digitization and, c) Miniaturization. It is necessary to introduce a group of concepts and skills in the company such as: a) The smart factory, b) Cyber-Physical Systems, c) Self-organized systems, d) New logistics management, e) New processes in the development of products and services, f) Adaptation to human needs, g) Corporate social responsibility (Ghobakhloo 2018). In Fig. 2 the relationship of satisfaction of motivators by enablers is shown.

Fig. 2: Motivators and technologies associated with I 4.0. (Modified from Zeid et al. 2019)

2.2 *Digital Transmormation (DT)*

DT consists on the integration of digital technology in all areas of a company, fundamentally changing the way it operates and provides value to its customers. While this is true, it is no less true that since the appearance of computers and electronics, innovation and technological creation have been present and the change in everyday life was what drove the use of emerging technologies, further driving digital transformation.

What technological evolution has done is to generate a greater number of opportunities associated with the generation of increasingly complex devices and applications that allow more flexible processes and timely data and information for better decision-making, these being the central aspects in the digital transformation. As a consequence, new technologies have changed the way people work, shop and even interact. This process of innovation and technological creation is not going to stop and its (good) use requires a minimum of training associated with different roles and levels of human endeavor, not only on personal and professional level, but also on business and public policy levels, among others.

Vial 2019 defines digital transformation as a process in which digital technologies create disruptions that trigger strategic responses from organizations that seek to alter their value creation routes while managing structural changes and organizational barriers that affect positive and negative results of this process, and more assertively define it as "…a process that aims to improve an entity by activating significant changes in its properties through combinations of Technologies, such as information, computing, communication and connectivity”

One of the entities, within industrial processes, whose transformative impact is considerable in DT is the transformation enabled by Information Technology (IT), which is not new and has been widely recognized in literature. Some of the strategic roles of IT from a DT view are:

- It induces automation, improving existing capabilities, efficiency and effectiveness, which are clearly identifiable and measurable in the processes.
- It establishes the process of translating descriptions and measurements of activities, events and objects into information (Informate-up), generating information towards the higher levels of decision-making, up to management (Management Information Systems), which improve decision-making, coordination and collaboration, whose benefits are not only tangible (increased sales, increased market share, reduced costs) but also intangible (brand awareness, customer loyalty, employee morale) . Companies that ignore intangible benefits tend to underperform over time, while those that strive to cultivate them prosper.
- It establishes the process of translating business objectives and goals into activities, events, slogans. This is from the managerial levels to the process levels (Informate-down) where the directives (goals, objectives) become activities at the lower levels of the decision-making process.
- It transforms, thereby redefining the business model, business processes and business relationships. As existing capabilities are changed, new capabilities are acquired, both internally (through reconfiguration) and externally (through strategic partnerships). The benefits in this case are difficult to anticipate, they include tangible and intangible benefits; fundamentally alters the company structure.

Using DT in order to achieve greater agility and flexibility in processes and timely decision-making, based on models, data and information, in principle, defines the following set of categories of activities that allow digital transformation:

Adaptation, where an evaluation is carried out, for example Analyzing data generated from sales to detect changes in customer demand, if possible in real time.

Translation, where either a development or a reconfiguration is made, for example developing a mobile application that allows customers to interact with the company in order to increase the number of customers or incorporating an operational backbone network to take advantage of digital services.

Integration, Either for strengthening or signaling, for example, incorporating functionalities of the company into the digital / cyber world in collaboration with IT or hiring experts in the process and business area, consultants in the automation area who hold positions such as: Executive Director (CEO), Chief Operating Officer (COO), Chief Marketing Officer (CMO), Chief Financial Officer (CFO), Chief Information Officer (CIO), Chief Technology Officer (CTO), Chief Communications Officer (CCO), Chief Digital Officer (CDO)) to show initiatives, even from other companies, DT and carry them out.

Expertise, either in Negotiation, Learning and / or Decision Making. For example meetings to define strategic transformation objectives in the short, medium and long term, enact a digital transformation strategy (all of the above) to allow the exchange of knowledge between the business/production units and IT, or improve the decision-making process using intuition by use based on evidence, particular case, use of data analytics, among others.

3 Need and aspects of a Methodology for the implementation of I4.0

As has been shown, when it is said that a company is within the category of I4.0, it is due to the fact that its (new) business conception is based on efficiency, care for the environment, responsibility with the client and with its staff that define the company as safe, smart and sustainable (Trentesaux et al. 2016). These three aspects encompass technologies aimed at satisfying the category set of activities associated with the company’s DT. Given this complexity of the TD process towards I4.0, it is important to have a methodology that serves as a guide for this purpose.

The methodology shown here was designed considering three aspects:

- A meta-model for the management of business and production processes, associated with the work of the company (capital flow vs product flow), using BPP, Business Model, Value Chain (Montilva et al. 2003), the ISA-95 standards (ISA-95 2000), and ISA-88 (ISA-88 2001) and the ARC 3-axis globe model.
- An integrated automation reference model, which is based on the MRAI reference model proposed in (Montilva et al. 2001), and the integration scheme described in (Chacón et al. 2008) that is shown in the Ontology for Production Systems and Control Architecture in the Process Integration of (Chacón et al. 2021).
- The use of the Holonic Production Unit approach, which conforms to the requirements of I4.0.

3.1 Meta-model of business and production process management

Every company has Business Models, Value Chains, an Organizational Structure, a mission, a vision, and some objectives already defined.

Using standards, such as the Business Model Method (BMM) and the Value Chain (Bernd 2011), allow us to capture the particular characteristics of each of the aspects of the Business System. The use of the standards ISA-95 (ISA-95 2000) and ISA-88 (ISA-88 2001) establishes a guide to describe the hierarchy of assets in the production process, as well as to project the master recipe on it. Defining the product model and the process model.

The use of the collaborative management model, given as a 3-axis globe model Colombo et al. 2014 provides a medium to think about all the complex interactions, applications, collaborations and processes that a company entails, see Fig. 3.

The 3 axes describe:

- Product Life Cycle domain axis, divided into design and support,
- Intra-Business domain axis, divided into Production Processes (plant floor) and Business Processes (business), associated with operations and decision-making,
- Value Chain domain axis, divided between suppliers and customers.

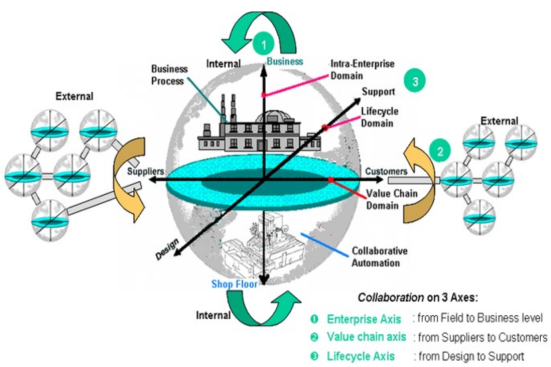

Fig. 3: Modelo ARC. Tomado de Colombo et al. 2014.

The globe allows defining the interactions between the 6 faces of the 3 domains on the axes.

3.2 A Reference Model of Integrated Automation

The reference model is focused on the activity based on the Product-Process-Resource (PPR) relationship (Cutting-Decelle et al. 2007, Pfrommer et al. 2013, Seitz et al. 2021) who define the dynamics of the organization (see Fig. 4) and on the description of a hierarchical control architecture defined in a 5-layer decision-making structure similar to the ISA-95 model (ISA-95 2000).

3.3 The Holonic Production Unit

The concept of Holon in manufacturing processes has been around since the last decade of the 20th century (Valckenaers et al. 1994, McFarlane 1995, Mathews 1995, Van Brussel et al. 1999). A Holon is defined as a whole and part of one. Being a whole, it defines its autonomy of interaction and action and being part of one, generates a larger-more

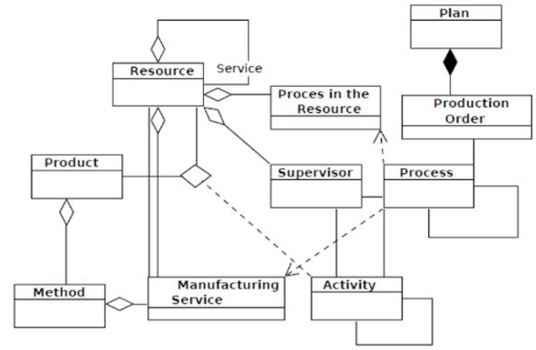

Fig. 4: Abstraction of the relationships between Process-Resource-Product

complex entity, for example: cell-organ-body, cell-unit-plant. In holonic systems, a holon can be made up of other holons and a base holon is made up of a decisional logical part and a physical part that implements the physical tasks. A Holonic Production Unit (HPU) is composed of a hierarchy of supervisors (decisional logical part), the Holon Supervisor and a person responsible for planning and executing the Activities that the manufacturing services achieve. The activities are associated with the Mission Holon, similar to the Order Holon in PROSA, the Engineering Holon that stores the knowledge of the HPU, and the Resource Holon that is made up of teams or other HPUs as can be seen in Fig. 5.

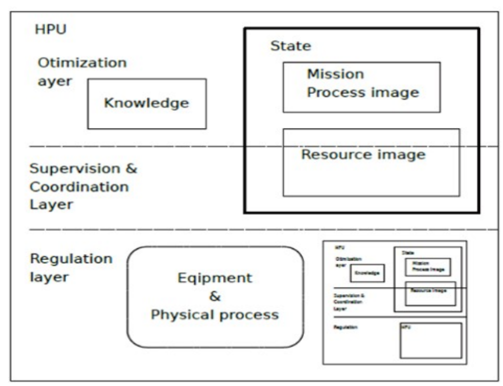

Fig. 5: Holonic Production Unit

The operation of the organization is subject to a decision-making structure, it is described by a 5-layer structure equivalent to the ISA-95 model (ISA-95 2000) with CPPS considerations given in (Monostori et al. 2016). The physical processes are in contact with layer 0, these are carried out by operators - machines and are controlled by operators - layer 1 systems, see Fig. 6. There are interactions between the different layers, as well as between the internal functions of each layer. The interaction diagram of each layer is shown in Fig. 6. A first validation of this approach is given in (Chacón et al. 2021)

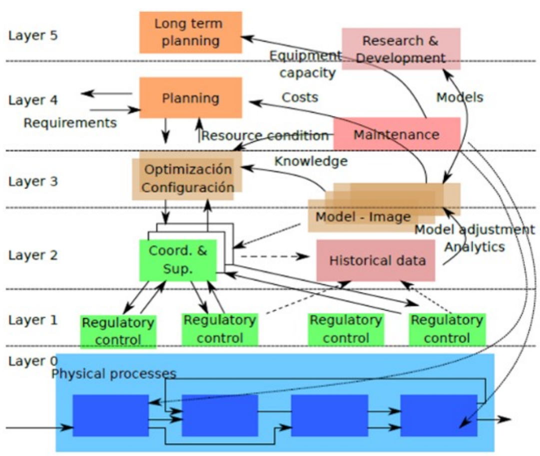

Fig. 6: Control architecture, taken from Chacón et al. 2021

As shown, the characteristics of the HPU are implicitly molded to accommodate all the considerations to establish at I4.0.

4 The Janus Methodology

It is a guiding instrument for Integrated Automation in production processes aimed at the digital transformation of companies under the Industry I4.0 approach. Its name is derived from the god "Janus" from Roman mythology, he was the god of portals, beginnings and ends, establishing changes and transitions, separating the past from the future towards evolution, in this case the evolution of the company. It is represented as two faces looking to both sides of its profile. Another aspect associated with the two faces of Janus in the methodology are those associated with the semantic technology defined by the interactions in the units (vertical integration) and between units (horizontal integration) that establish the dialectic (communication, messages, documents, materials), based on their behavior. The internal behavior (set of internal variables of the process) of a unit defines its state, these new variables (indicators) are the variables used that describe the behavior of the interaction between units. Thus, instead of having a single global model defined as the composition of the internal models of each unit, there are as many internal models as there are units and a behavior model that defines the behavior of the interaction between units. This scheme allows defining the integration elements and the appropriate technologies for their integration, dealing with complexity, maintaining the autonomy of the units, including data and information security.

While it is true, not all companies can be determined to be I3.0 as a premise to go towards 4.0. The approach can be used to make improvements in the production process that will carry its essence and therefore a continuous improvement of the company puts it on the path to go towards I4.0

The methodology is expressed in terms of Continuous Improvement or Deming Cycle (Kanneganti et al. 2017) and has 6 cyclical Phases, see Fig. 7, associated with a continuous improvement scheme, which allow progressively to achieve I4.0, The phases are as follows:

1) Determine the Status of the Company
2) Carry out a Diagnosis (gap towards I4.0)
3) Opportunity map (towards I4.0)
4) Economic feasibility
5) Implement each prioritized option:
   a) Define the Implementation path of the option
   b) Execute the implementation of the path
   c) Monitoring the Implementation of the path
   d) Evaluate compliance with the implementation of the path
6) Start, go to step 1 start the cycle of other improvements

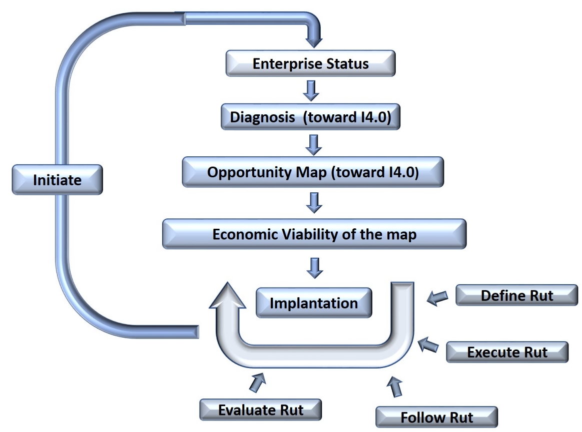

Fig. 7: Janus Methodology

An important and fundamental requirement is that those involved by the company in using and applying the methodology together with the experts must know the concepts, arguments, standards associated with the I4.0 approach.

4.1 Structure of the Methodology

The methodology is structured in phases, steps and tasks. Each of the phases contains a set of steps and these are tasks to be carried out.

4.1.1 Phase 1: Determine the Status of the Company

In order to determine the Status of the Company, the following question must be answered: How is the company with respect to itself or an equivalent in optimal condition? The input at this stage is the following information:

1) Enterprise description

- Objective,
- Mission,
- Vision
- ¿What does it do?
- ¿For whom?
- Organizational structure

2) How does it do it?, and with what or with whom?
   a) User requirements regarding production activities:
      - Quality
      - Monitoring and supervision
      - Planning
      - Performance evaluation
   b) Handling of:
      - Processes involved and
      - Products and their presentation
      - Resources: Maintenance, Human resource
      - Inventory: Material, products
      - Business: Purchases - Suppliers, Sales - Customers
   c) Production - Business Integration

It is very important to define correctly: How do you do it? And with what or with whom? The analysis of this information by the experts shows the level of systematization of the processes, the coherence of its business-processes model, the interaction between the levels and the decision-making schemes, The analysis includes an inventory and its relationships of the set of applications and systems of the company. This allows obtaining a good approximation on the level of automation and integration

The result in this stage is the analysis carried out on the information collected, which defines the status of the company, which answers the question, how is it with respect to itself or an equivalent in optimal state? The information collected must be structured as follows:

1) Structure:
   a) Handling of business-production processes, use BMM, and Chain Value:
      - Fundamentals
      - Support
      - Orders
   b) Assets hierarchy, use ISA95, ISA88
2) Condition of Resources-Units
   a) State of Resources-Units
   b) Systematization of the Process
   c) Automatization of the Process
   d) Materials, supplies, products
3) Establish the relationship and compatibility of the I^5 between the units: Interaction, Interrelation, Interconnection, Interoperation, and Interface.

4.1.2 Phase 2: Make a Diagnosis (gap towards I4.0)

Remember that the premise of I4.0 is to be a fully integrated and automated company. The result of the previous phase shows us, broadly speaking, the level of systematization, integration and automation that the company has. Not having the required level to advance immediately to I4.0 is not an impediment to not making associated improvements in order to achieve it. The methodology considers both cases and for this reason the need for diagnosis.

To carry out the diagnosis, besides the information obtained, the following aspects must be complemented and completed:

1) Complete-define the Value Chain of the Production Process, carry it out in as much detail as possible, consider the following aspects:
   - Define Production Units, it is suggested to have at least 3 levels that include the activities.
   - Define functional units: roles / skills, methods.
2) Complete the hierarchy of assets, identified on the units of the value chain. Include description of the teams, their status, skills and competencies.
3) Complete the description of products, master recipes, product routes.
4) Complete the description of the materials, their handling and storage.
5) Generate the product flow models, for example using UML, these must contain
   - Description of production methods.
   - Skills-Competencies required, who and why, verify with the information of the asset hierarchy, item 2.
   - Required raw material, when it is transferred, is incorporated in the production process stage, according to the master recipe.
   - Description of actors, ressources and instants: who, why, when, how, within the product flow.
6) Generate the process flow diagrams, for example using UML, these must contain:
   - Logical and physical requirement.
   - Set of activities.
   - Documents and trigeering processes.
7) Describe the functions of business and production processes, for example using IDEF 0 diagrams. 3 levels are suggested including the level of activities. It must be established:
   - The flow of documents, information and product.
   - The association of documents and information with product flow within entities and between entities.
8) With the maps obtained (Value chain, UML diagrams and IDEF 0 diagrams) combine and standardize processes, activities, flows of documents, information and materials.
9) With the homogenized maps, establish with whom and

with what the functions and activities are carried out. The result in this stage is an inventory of the ways in which procedures and activities are carried out (manual, automatic, semi-automatic with human intervention) and an inventory of applications and systems that are used for this purpose.

With the information obtained, a diagnosis, between the company's team and the experts, is made regarding the conditions of I4.0.

4.1.3 Phase 3: Phase 3: Opportunity Map (towards I4.0)

At this point, having determined the gap between the current state of the company and what is required by I4.0, it is important for the company to be clear about two aspects: the first if it maintains or changes its work (widens, reduces or changes) and for whom it does it (types of customers) since this can introduce major changes in the improvements to be made and the second aspect is what is the level of integration, automation and sustainability as a green company that it wants to achieve. With these two aspects, the project group establishes the set of improvements in each area, level, and process associated with the digital transformation requirements to achieve the agreed goal. The result of this phase is a map of opportunities towards I4.0

4.1.4 Phase 4: Economic feasibility

With the opportunity map of the previous stage, the economic viability of each of the opportunities is defined taking into account the return on investment (ROI), this includes the criteria and their order of precedence with which the map will be evaluated, depending of the particular case of each company, the following aspects should be considered:

- Innovation and creativity (new proposals)
- Impact on the organizational structure
- Impact on fundamental processes both in the business and the production area.
- Training, hiring or change of personnel
- Human impact: Customer-employee-suppliers
- Customer centered

The result of this phase is the prioritized list of the set of improvements to be implemented according to the defined criteria.

4.1.5 Phase 5: Implementation

For each option, a set of steps is applied, equivalent to the Deming Cycle to have a guide for the evolution and evaluation of the option to be implemented. The set of steps are:

1) Define the Implementation path of the option: The set of stages, requirements, and the schedule are defined according to the specificity required, the aspects indicated in 4.1.4 must be considered.
2) Execute the Implementation path: For this and the next steps in this phase, a team made up of company personnel and consultants is required to manage the implementation project. It is suggested to involve staff from the floor, unit or site. It is suggested to use a standard and a project management application.
3) Follow the Implementation path: The implementation project management teams will monitor the project, the following aspects must be taken into account:
   - Preventive Actions
   - Corrective Actions
   - Audits
4) Evaluate compliance with the path: The management teams of the implementation project will carry out the evaluation of compliance with the path, the following aspects must be taken into account:
   - Impacts of changes
   - Suggestions

4.1.6 Phase 6: Start, start the cycle again

Before carrying out a new application of the methodology with a new cycle of improvements, it should be taken into account that:

- There are improvements that cannot be made without a previous improvement, but there are cases where it is possible to carry out more than one improvement at a time. Making improvements in parallel is in principle limited to budget and staff deficits.
- Once the implementation has been carried out, a time must be established to measure the effects of the improvement made. This is accompanied by indicators.

At the end of the sixth phase, the methodology is applied again to continue continuous improvement until reaching I4.0.

5 Discusión

This methodology is the result of compiling the group's expertise in the integration of continuous production systems and in the application of the HPU approach to the automation of processes, which coincides with what is expressed in the digital transformation of companies using the I4.0 approach.

In order to implement the I4.0 approach, those involved in the company must have knowledge about the approach and its requirements. Also, it needs to be clear to what level the company wants to go, that sets the goal and defines the gap between being I4.0 and the current state.

The Methodology is a guide for companies to go towards I4.0, in the same way it is applicable to SMEs and Entrepreneurships with some adjustments.

The concepts associated with business and production must be within the technological semantics of those involved in the project.

Need for experts in Integration and I4.0 is essential this is the use of consultants, not companies that sell equipment.

The working group that developed this methodology also developed a web application to establish in a very general way a diagnosis for companies from the perspective of digital transformation towards I4.0. The company SIMAC SA from Medellin Colombia has kindly provided this free application for companies, SMEs, Entrepreneurships on its web portal. To access the application, go to this address https://simac.com.co/ or http://www.ind40diag.com/

The methodology has been applied to the agro-industrial sector in Venezuela and to companies in the manufacturing and food sector through consultancies with the Company Simac in Medellín Colombia.

6 Conclusions

The methodology offers a way to achieve Digital Transformation in SMEs in the region in a simple way, and that takes into account the difficulties in obtaining specialized personnel within organizations, in the area of modelling and automation.

The described methodology is a guide that is based on the continuous improvement of production processes with the aspects of Industry 4.0 regardless of the level of systematization, integration and automation that currently exists.

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