The International Journal of Engineering and Science (IJES)
|| Volume || 8 || Issue || 8 Series II || Pages || PP 31-36 || 2019 ||
ISSN (e): 2319 – 1813 ISSN (p): 23-19 – 1805

# Proposal for a Smart Factory implementation Model based on Industry 4.0

L.A.E José Oscar Rocha Bautista[1], Dr. Miguel Ángel Rodríguez Lozada[2],Dr. Jorge Luis Castañeda Gutiérrez[3]

*[1]Division of postgraduate studies and research, National Technological Institute of México, Technological Institute of Apizaco,, Tlaxcala, México*
*[2]Division of postgraduate studies and research, National Technological Institute of México, Technological Institute of Apizaco, Tlaxcala, México*
*[3]Division of postgraduate studies and research, National Technological Institute of México, Technological Institute of Apizaco, Tlaxcala, México*
*Corresponding Author:L.A.E José Oscar Rocha Bautista*

**ABSTRACT**

*Currently, there are some reference architecturesto develop Industry 4.0 and implement processes to migrate organisations to the so-called Industry 4.0. All of themhave specific purposes and structures. However, it is necessary to recognize and analyze the compatibility of said reference architectures in order to adequately complement their characteristics. This paper describes seven key aspects of four reference architectures for Industry 4.0 defined through a research from a previous work, present a compatibility analysis scheme of the key aspects elements and finally a proposal for a Smart Factory implementation model is shown.*

***KEYWORDS;-****Reference Architecture, Industry 4.0, Smart Factory, Smart Manufacturing, Model*

Date of Submission: 21-08-2019 Date of acceptance: 05-09-2019

## I. INTRODUCTION

The term Industry 4.0 was introduced in 2011 by the group of communication promoters of the Industry-Science Research Alliance in Germany, to describe the broad integration of information and communication technologies in industrial production, in which term the "4.0", hints at how the potentially revolutionary impact of this trend precedes three previous industrial revolutions [1]. In a simple way, Industry 4.0 can be referred to as the technological evolution of embedded systems to Cyber-Physical Systems (CPS), an example of this is a Smart Factory [2]. The search for the correct and most effective way to migrate the different companies to Industry 4.0 has been continuously intensified since the appearance of this concept.

Government initiatives of Industry 4.0 have been launched in different countries around the world with the aim of helping stakeholders to correctly and efficiently guide their transition towards the new challenge represented by the arrival of the new industrial revolution. That is the case of countries such as Germany; through the Platform Industry 4.0, which aims to develop joint recommendations for all stakeholders that serve as the basis for a consistent and reliable framework [3]. USA; through the Industrial Internet Consortium (IIC), which has the objective to transform business and society by accelerating the adoption of Industrial Internet of Things (IIoT) [4]. Japan; with the Industrial Valuechain Initiative (IVI), a forum to design a new society by combining manufacturing and information technologies, and for all enterprises to take an initiative collaboratively [5]. China; through Made in China 2025, which aims to keep the same pace with the world and the core to realize transformation and upgrading [6].

These four initiatives are especially important since within their respective platforms they have proposals for reference architecture of Industry 4.0. In any case, it is important to add that countries such as Spain with its "Connected Industry 4.0" or the United Kingdom with "The catapult programee" among others also have similar Industry 4.0 initiatives but do not have reference architectures [7, 8]. In this paper, seven key aspects of four the reference architectures for Industry 4.0 that were defined from a previous research are analyzed: Germany, USA, Japan and China, are the countries from which they come.They have special relevance as a starting reference for the creation of the proposed model due to its technological prominence worldwide.

Regarding the methodology used to carry out this research work, the following elements that guide the design of the model sought have been defined.

| CHARACTERISTICS FOR THE METHODOLOGY | DESCRIPTION |
|---|---|
| Documentary | Analysis of different sources of data |
| Descriptive | Description of a phenomenon |
| Transversal | Time and population pre-defined |

**Table 1**.Elements of the research. Source: Own elaboration (2019)

| METHODOLOGICAL STAGES | DESCRIPTION |
|---|---|
| Recollection of data | Predefined by a previous research (Reference Architectures) |
| Define a tool for analysis | Analysis of main aspects matrix |
| Analysis of data | Obtaining results |
| Model design | Design of a proposal based on data |

**Table 2**.Methodological procedure. Source: Own elaboration (2019)

## II. MAIN ASPECTS OF INDUSTRY 4.0 REFERENCE ARCHITECTURES

**Reference Architecture Model Industry 4.0 (RAMI)**

RAMI of German origin is a three dimensional coordinate system that describes all crucial aspects of Industry 4.0. Below are the seven key aspects that describe this architecture.

| ASPECT | DESCRIPTION |
|---|---|
| 1. Type of architecture | A conceptual three-dimensional architecture composed of layers. |
| 2. Objective | Convergence of the physical and digital worlds, specifically Information Technology (IT) and Operational Technology (OT) and development of concrete system architectures. |
| 3. Target audience | Readers from German industry, the relevant technology-oriented sectors, research and government. In particular, managers, experts and consultants. |
| 4. Application area | Vertical and horizontal – more broadly horizontal. Understanding vertical as de application among the factory and horizontal beyond the factory. |
| 5. Core of the architecture | Manufacturing |
| 6. Application methodology | RAMI breaks down tasks, workflows and other complex interrelations into manageable parts. |
| 7. Structural axes | Long (x), Life Cycle and Value Stream; wide (y), Hierarchy Levels; high (z), Layers. |

**Table 3**.Reference Architecture Model Industry 4.0 (RAMI),main aspects. Source: Own elaboration based on P. Adolphs et al., (2015)[9].

**Industrial Internet Reference Architecture (IIRA)**

IIRA of American origin is a standards-based open architecture for IIoT systems. Below are the seven key aspects that describe this architecture.

| ASPECT | DESCRIPTION |
|---|---|
| 1. Type of architecture | A conceptual three-dimensional architecture composed of layers. |
| 2. Objective | Convergence of the physical and digital worlds, specifically Information Technology (IT) and Operational Technology (OT) and development of concrete system architectures. |
| 3. Target audience | IIoT system architects, plant managers, IT managers, business managers and other interested parties. |
| 4. Application area | Horizontal and vertical but more broadly horizontal. Understanding vertical as de application among the factory and horizontal beyond the factory. |
| 5. Core of the architecture | IIoT systems. |
| 6. Application methodology | IIRA drives interoperability, maps applicable technologies and guide technology and standard development. |
| 7. Structural axes | long (x), Industrial Sectors; wide (y), Lifecycle Process ; high (z), Layers |

**Table 4.** Industrial Internet Reference Architecture (IIRA), main aspects. Source: Own elaboration based onS. Lin et al., (2017) [10].

**Industrial Valuechain Reference Architecture (IVRA)**
IVRA of Japanese origin is a structure of smart manufacturing. Below are the seven key aspects that describe this architecture.

| ASPECT | DESCRIPTION |
|---|---|
| 1. Type of architecture | A conceptual three-dimensional architecture composed of layers. |
| 2. Objective | To achieve Smart Manufacturing. |
| 3. Target audience | Manufacturers and interested parties. |
| 4. Application area | Vertical and horizontal but more broadly vertical. |
| 5. Core of the architecture | Smart Manufacturing Unit (SMU). |
| 6. Application methodology | IVRA maps the framework in SMU's, executes the Exploration-Recognition-Orchestration-Realization (EROR) cycle and performs a technical organization of its systems. |
| 7. Structural axes | Long (x), Service; wide (y), Product ; high (z), Knowledge, theses axes can be found in the Sub-Business layer represented by the three sets of arrows. |

**Table 5.** Industrial Value Chain Reference Architecture (IVRA) main aspects. Source: Own elaboration based onIndustrial Value Chain Initiative (IVI) (2018)[11].

**Intelligent Manufacturing System Architecture (IMSA)**
IMSA of Chinese originis a structure of smart manufacturing. Below are the seven key aspects that describe this architecture.

| ASPECT | DESCRIPTION |
|---|---|
| 1. Type of architecture | A conceptual three-dimensional architecture, composed of layers. |
| 2. Objective | To guide the standardization of intelligent manufacturing. |
| 3. Target audience | Manufacturing industry. |
| 4. Application area | Vertical. |
| 5. Core of the architecture | Manufacturing. |
| 6. Application methodology | IMSA maps manufacturing systems and relates them to industry standards. |
| 7. Structural axes | Long (x),Systems Hierarchy; wide (y), Lifecycle; high (z), Intelligent Functions. |

**Table 6.** Intelligent Manufacturing System Architecture (IMSA), main aspects. Source: Own elaboration based onSino-German Industry 4.0/Intelligent Manufacturing Standardization Sub-Working Group (2018) [12].

## III. RESULT VIEW

The following relational scheme is shown in Table I as a proposal to analize the compatibility of the reference architectures through their characteristics, where the "=" sign corresponds to the fact that the characteristic is equal or almost equal to at least one other in the same row, the "+" sign corresponds to the characteristic that is complementary to the others in the row, and the "≠" sign corresponds to the fact that the characteristic is different from all the others in the respective row.

| **Key Characteristic** | **Reference Architectures for Industry 4.0** | | | |
|---|---|---|---|---|
| | **RAMI** | **IIRA** | **IVRA** | **IMSA** |
| 1. Type of architecture | = | = | = | = |
| 2. Objective | = | = | + | + |
| 3. Target Audience | + | + | = | = |
| 4. Application area | = | + | = | + |
| 5. Core of the architecture | = | ≠ | = | = |
| 6. Application methodology | + | + | + | + |
| 7. Axes | + | + | ≠ | + |

**Table 7.**Analysis of mains aspects for Industry's 4.0 architectures. Source: Own elaboration (2019)

**Smart Autonomous Factory Model**
Based on the results obtained in each of the stages of the methodology, the following model proposal is achieved; Smart Autonomous Factory Model (SAFAM).

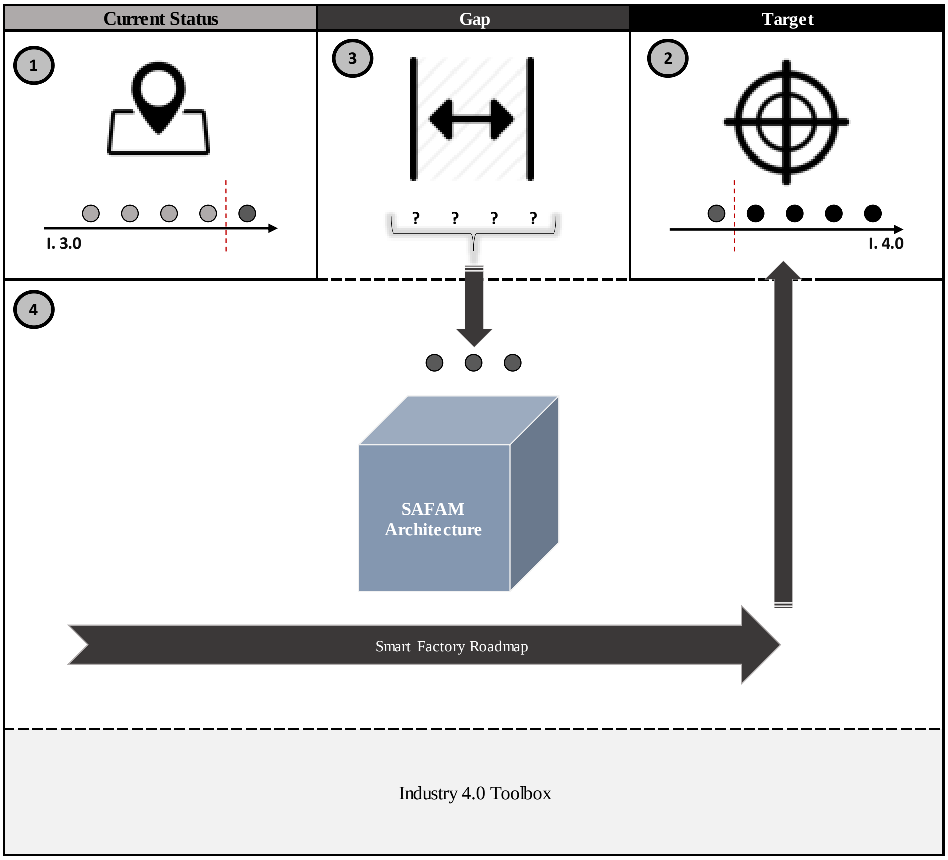


**Figure 1.**Smart Autonomous Factory Model.Own elaboration (2019)

The SAFAM model consists of 5 sections that guide the development of the transition from a normal Factory to a Smart Factory, this model consists of a Base (Industry 4.0 Toolbox), a body (SAFAM Architecture) and three contiguous stages:

1. Current Status: defines the degree of maturity of the current factory
2. Target: defines the desired status
3. Gap: The difference that exists between the current status and the desired one.

In the first instance, through an Assessment, the Current status of industry 4.0 is defined, then the objective Target that is pursued as agreed between the interested parties and the project leader is defined and finally the Gap between these two sections is identified, over which development actions must be designed to achieve the desired status.

Based on the results of the Assessment, it is strongly recommended to place the result of normalizing the highest score towards the other areas as “Target”, that is, in the case of the example in Figure 4.1.3, the “Target” would consist of reaching the highest score among the four areas analyzed.

To properly define the “Target” it is recommended not to exceed a unit based on the highest value obtained in the Assessment, in the case of the example the objective could consist of a maximum score of 4.4 for all areas, in addition to the times for the Achievement of the objective must not exceed 1 year in order to avoid defects in the processes, technological obsolescence and low or zero levels of control and structural rethinking of strategies.

To carry out periodic checks on the development of the project, each organization must implement its own style of “Project management”, however, an excellent idea is to carry out methodologies such as SCRUM which is indicated for projects that address complex adaptive problems, through work teams that work in a light or agile way with the objective of delivering the maximum possible value from the productive and creative point of view.

| SAFAM Asessment overview | | | |
|---|---|---|---|
| Resources | Information Systems | Organisational Structure | Culture |
| 3 | 2.2 | 3.4 | 3 |

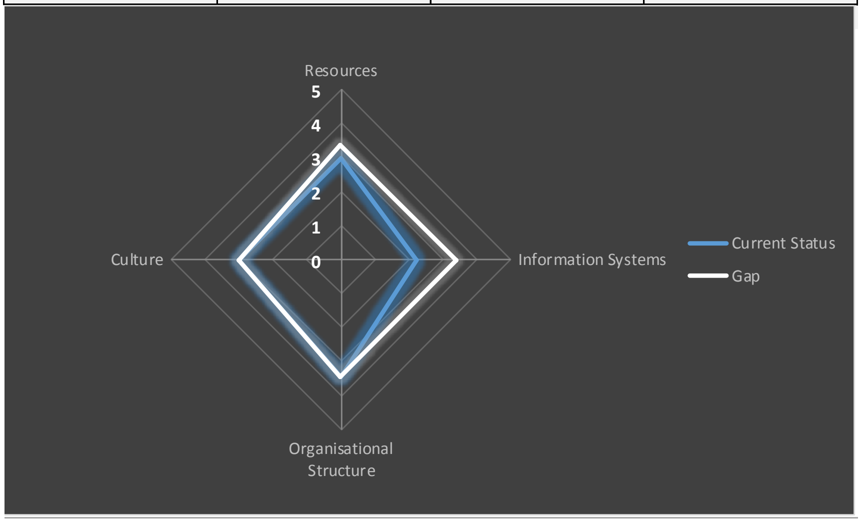


**Figure 2.**SAFAM Assessment example. Source: Own elaboration (2019)

Within the architecture (body) there are 3 axes that are described below:
• Structural areas axis: Describes the structural areas within an organization, each of its elements are displayed throughout all the functional areas of the company. It should be noted that within this axis there are elements such as Culture and the organizational structure that despite not being a direct part of the change at the technical level, form a core section in the achievement of the objectives of Industry 4.0 as well described to throughout this research work.
• Functional areas axis: Within this section you can locate the four functional areas of any company, they represent the direct starting point on which strategies for the practical application of Industry 4.0 development will be developed.
• Maturity 4.0 axis: This axis evaluates the maturity level of Industry 4.0 in the form of a three-dimensional matrix for the two previous axes, it is the main aspect of architecture analysis, from the maturity level of each organization development actions will be generated either for structural, functional areas or a set of both.

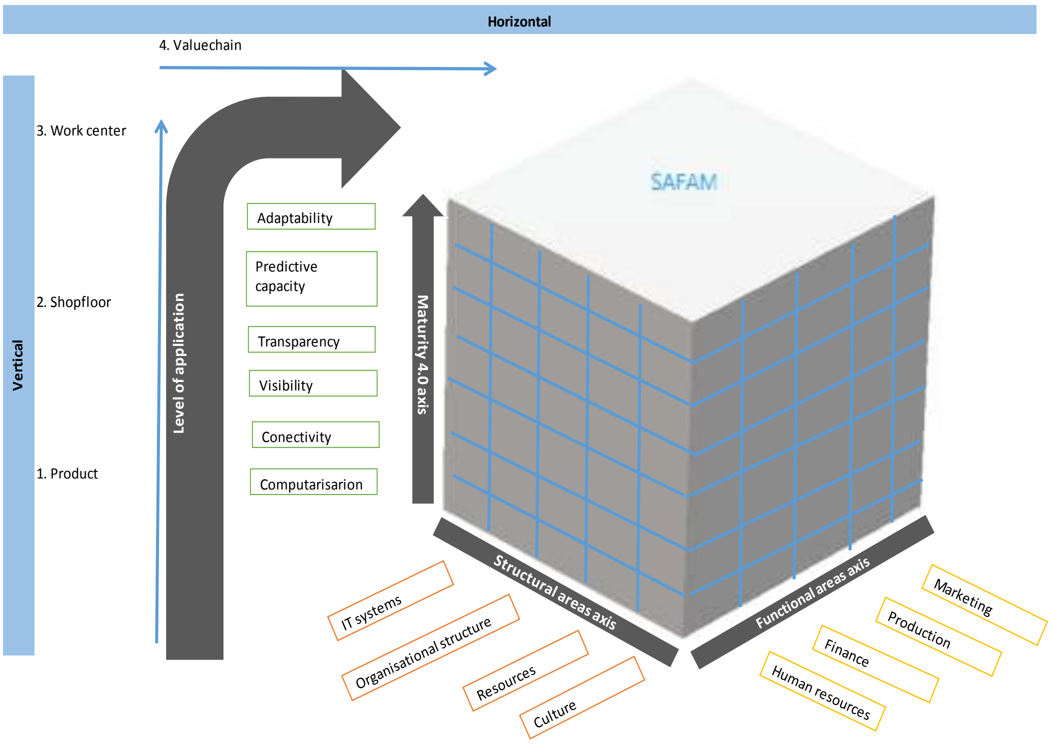


**Figure 3.**SAFAM Architecture. Source: Own elaboration (2019)

## IV. CONCLUSION

Regarding the proposed model, previous works found in the literature have been taken as the basis for development.

The ideal path to Industry 4.0 is still unknown and this will probably not change in the near future. There are currently many organizations in search of obtaining the desired title of Smart Factory for a very simple reason, represents the future; and with the future also a paradigm shift towards sustainable organizations, highly efficient, flexible to changes and with products of unparalleled quality only made possible through science and technology.However, since an organization intends to arrive at the so-called fourth industrial revolution, it is concrete and adds efforts to reach an action plan that will lead to obtaining the desired status. Currently, more and more organizations, institutions and private companies are inclined to invest and develop strategies and technologies that facilitate the transition of organizations to Industry 4.0.

In the case of this investigation, the proposal of a model that guides the transition from a normal Factory to a Smart Factory has been carried out giving as main result the SAFAM model, however the following findings can be referred as part of this research:

• A model is an abstraction of reality and is a work with logical and heuristic scientific elements.

• To reach an objective in the technological and cultural transition whatever this may be, four fundamental elements are required: the definition of the current status, the definition of the desired status, the gap between the current and desired status and the method of covering the existing gap.

• A Smart Factory works under a single focus and vision; that of an intimately related organization as well as seen and performed from a holistic perspective.

• The technologies of industry 4.0 are primarily characterized by three elements: they are connected to the Internet; they have the power to transfer input and output data with other entities in the environment and have the ability to collect large amounts of data through sensors automatically

• One of the best practices in the development of industry 4.0 is to develop processes and innovate from a holistic point of view through which organizations are seen as what they are, intimately related systems and not as departments or organizational units isolated.

## REFERENCE

[1]. G. Schuh, R. Anderl, J. Gausemeier, M. Hompel, and W. Wahlster, “Industry 4.0 Maturity Index. Managing the Digital Transformation of Companies,” acatech STUDY, Munich, 2017.

[2]. W. McDougall, “Industrie 4.0. Smart Manufacturing for the future,” Germany Trade and Invest (GTAI), Berlin, 2014.

[3]. Plattform Industrie 4.0. [Online]. Available: https://www.plattform-i40.de/I40/Navigation/EN/Home/home.html

[4]. S. Lin et al., (2017). Architecture Alignment and Interoperability. [Online]. Available: https://www.iiconsortium.org/pdf/JTG2_Whitepape

[5]. r_final_20171205.pdf

[6]. Industrial Value Chain Initiative (IVI) . What’s IVI? [Online]. Available: https://iv-i.org/wp/en/about-us/whatsivi/

[7]. National Intelligent Manufacturing Standard System Construction Guidelines (2015). [Online]. Available: https://www.cdti.es/recursos/doc

[8]. /Programas/Cooperacion_internacional/Chineka/Documentacion_relacionada/17668_273273201814238.pdf

[9]. Industria conectada 4.0. [Online]. Available: http://www.industriaconect

[10]. ada40.gob.es/Paginas/index.aspx

[11]. The Catapult Programee. [Online]. Available: https://catapult.org.uk/

[12]. P. Adolphs et al., “Reference Architecture Model Industrie 4.0 (RAMI4.0),” VDI/VDE, Düsseldorf, 2015.

[13]. S. Lin et al., (2017). The Industrial Internet of Things Volume G1: Reference Architecture. [Online]. Available: https://www.iiconsortium.o

[14]. rg/IIC_PUB_G1_V1.80_2017-01-31.pdf

[15]. Industrial Value Chain Initiative (IVI), “Industrial Value Chain Reference Architecture-Next,” IVRA Next, Tokyo, 2018.

[16]. Sino-German Industrie 4.0/Intelligent Manufacturing Standardisation Sub-Working Group “Alignment Report for Reference Architectural Model for Industrie 4.0/Intelligent Manufacturing System Architecture,” Berlin, 2018.

L.A.E José Oscar Rocha Bautista" Proposal for a Smart Factory implementation Model based on Industry 4.0" The International Journal of Engineering and Science (IJES), 8.8 (2019): 31-36