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From the Current Industrial Stage to the Industry 4.0: Transformation Processes and Case Analysis of the FESTO Company

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Despite of the acceleration of investments and the expansion of countries towards the Industry 4.0, companies have difficulties in planning the transition processes and implementation of the scenarios of Industry 4.0. To benefit from the Industry Approach 4.0, it is necessary to take technological and organizational transition processes into account, since the phenomenon involves interoperability between humans; between humans and machines; and between machines and production. This paper proposes to examine the transformation processes of the current industrial model to the Industry 4.0 model of FESTO AG, in addition to the framework proposition for the analysis of transformation processes for Industry 4.0. Through the face-to-face interviews and the institutional materials of FESTO, it was observed that the company inserted in its strategy of products and innovation the concept of Industry 4.0. To do so, FESTO planned and built a new production plant based on connectivity, sustainability, and collaborative environment, especially between man and machine. To support this orientation, FESTO has strengthened its technological base, culture, training of its productive, commercial, and management teams.

Keywords: Industry 4.0, competitiveness, industry, transformation processes

Introduction

The low production costs achieved by emerging countries have imposed a new standard of competition for the most economically advanced countries. In this context, the debate about the so-called Industry 4.0 emerges, which raises the importance of customization associated with the reduction of costs and mass production. This concept involves, among other things, real-time access to relevant information about the product, about the production and manufacturing automation (Brettel, 2014).

The term "Industry 4.0" became well-known in 2011 when a initiative named "Industrie 4.0" promoted the idea of bringing together business representatives, public authorities, and the scientific system to strengthen the competitiveness of German industry (Kagermann, Lukas, & Wahlster, 2011). There are also other terms underlying the concept, such as "integrated industry" (Bürger & Tragl, 2014, p. 560); "intelligent industry" and

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"intelligent manufacturing" (Dais, 2014, p. 628; Davis, Edgar, Porter, Bernaden, & Sarli, 2012, p. 145; Wiesmüller, 2014, p. 1).

Industry 4.0 emerges from the enterprise manufacturing structures with very peculiar characteristics, among them the orientation of areas, such as production, products, and logistics, marketing to customization by the specific needs of the client; integration of partners and customers; use of engineering throughout the production value chain and product life cycle; and combination in the use of exponential technologies (Deloitte, 2015). Industry 4.0 can also be understood as a new level of organization value chain management through the product lifecycle (Plattform Industrie 4.0, 2014).

Due to the very nature of the Industry 4.0 concept, the transformation to this paradigm is highly dependent on technologies, such as 3D printing, technological sensors, artificial intelligence, robotics, and nanotechnology, to compose intelligent machines, information storage systems, and production facilities that are capable of exchanging information autonomously, triggering actions, and controls independently.

One of the great potentials of Industry 4.0 is the smart factories, which are allowed to meet customer-customized requirements and produce reliably from the process engineering intervention (Kagermann, Wahlster, & Helbig, 2013). In this sense, it is fair to say that the combination of intelligent products, the Internet of Things in manufacturing and people has the potential to affect the value chain of companies, allowing the creation of new business models and the conduction of a new socio-technical structure in the place of work (Kagermann et al., 2013; Kagermann, 2014; Kempf, 2014).

According to Kagermann et al. (2013), although Germany is the most important country in the process of expanding the debate on industrial manufacturing 4.0, Asian countries, the USA and other European countries continue to expand the significance of the theme and promote action in that direction.

In the period from 2004 to 2008, there was a dramatic slowdown in production at German manufacturing plants and machinery. In the USA since 2002, the large-scale transfer of production to other parts of the world has resulted in a sharp rise in import dependence in the mechanical engineering sector (Kagermann et al., 2013). On the other hand, China has devoted great effort to achieve density in the field of mechanical engineering and strengthening its position in the world market. From 2008 to 2013, China was the largest producer of machinery in the world, with sales of 563 billion Euros in 2011, as well as being the fourth largest machinery exporter in the world, with a 10.2% market share. In addition, Russia has increased its machinery production since 2010 and has already established itself as the fourth largest exporter to German mechanical engineering companies, behind China, the USA, and France, as shown in Figure 1 (Kagermann et al., 2013).

Despite the acceleration of investments and the expansion of the countries towards the Industry 4.0, companies have difficulties in planning the transition processes and implementation of the Industry 4.0 scenarios (Gregor, 2009, p. 7; Eco, 2014).

In the literature on the processes of industrial change, different interpretations on the impacts related to industry are pointed out. Most authors agree with the high potential of increasing productivity to current industrial processes (Wahlster, 2013; Brettel, 2014; Imtiaz & Jasperneite, 2013). Despite this perception under the expansion of productive capacity, in order to benefit from the Industry 4.0 Approach, it is necessary to take into account technological and organizational transition processes, since the phenomenon involves interoperability between humans; between humans and machines; and between machines and production (Schuh, Reuter, Hauptvogel, & Dölle, 2015; Thames & Schaefer, 2017).

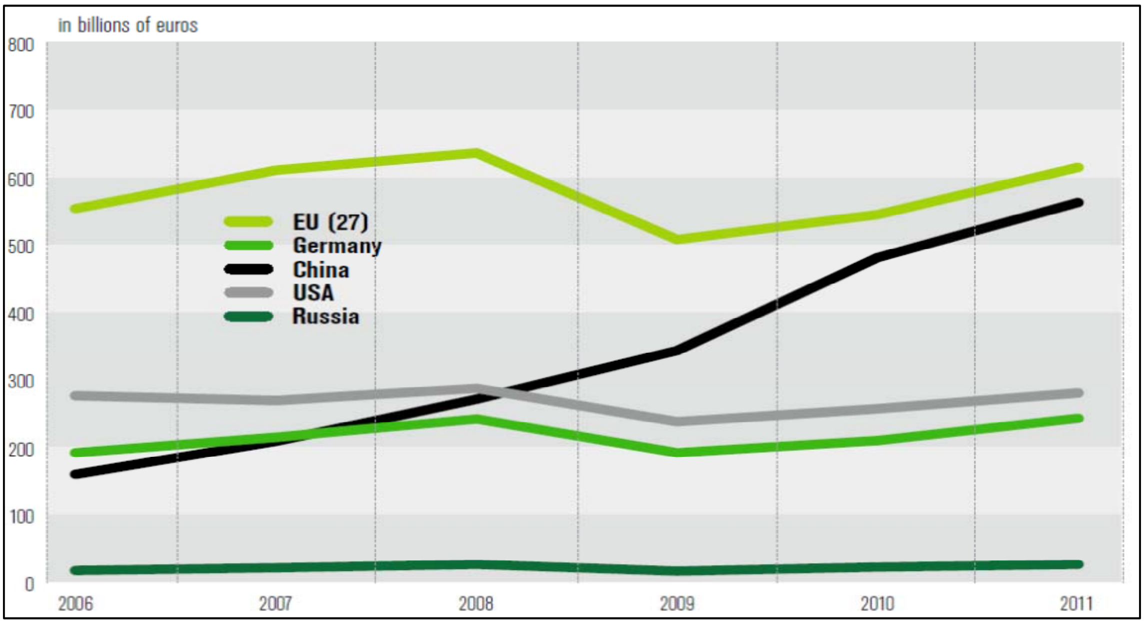

Figure 1. Sales of the mechanical engineering industry in selected countries (in billion of euros). Source: Kagermann et al. (2013).

FESTO is one of the leading suppliers of the world for automation technology. The company is present in 176 countries worldwide, with several factories around the world (FESTO, 2016). In the light of the above, this paper proposes to examine its transformation processes from the current industrial model to the Industry 4.0 model, in addition to proposing a framework for analyzing the transformation processes of the current industrial model for Industry 4.0.

Review of the Literature

Tech-Economic Paradigms in Capitalist Development

Throughout the history of the great capitalist development landmarks, tech-economic paradigms have emerged in productive systems, that is, product, process, technical, organizational, and administrative innovations have been combined, opening a range of investment and profit opportunities in their respective Periods of history. Each tech-economic paradigm was characterized by a specific set of inputs and technologies (Perez, 2010).

The main innovations introduced by the first industrial revolution concerned mainly the creation of the steam engine, which spread from industry to transportation, revolutionizing the operation of the whole economy. The second industrial revolution was characterized by the introduction of cheap steel, the ability to generate and distribute in a stable way electrical energy, from the engine to the explosion and notably from what is known as scientific management, which concerned the rationalization of production in the factory floor, easily seen in the diffusion of assembly lines (Rauen, 2006). The third industrial revolution emerges from the generation of so-called information technologies, responsible for the generation, storage, processing, and diffusion of information in scientific, technological, and productive systems (Castells, 1999).

According to Figure 2, Industry 4.0 (also referred to as the 4th Industrial Revolution, due to its impact on technological, economic, and social systems) is based on the incorporation of machinery, information storage systems, and production facilities, notably in the format of cyber-physical systems, which represent the fusion of the physical and virtual worlds (Kagermann, 2014, p. 603) and understand the integration of computation and physical processes. Embedded computers, network monitors, and physical process control, usually with feedback hooks where physical processes affect computing and vice versa (Lee, 2008, p. 363).

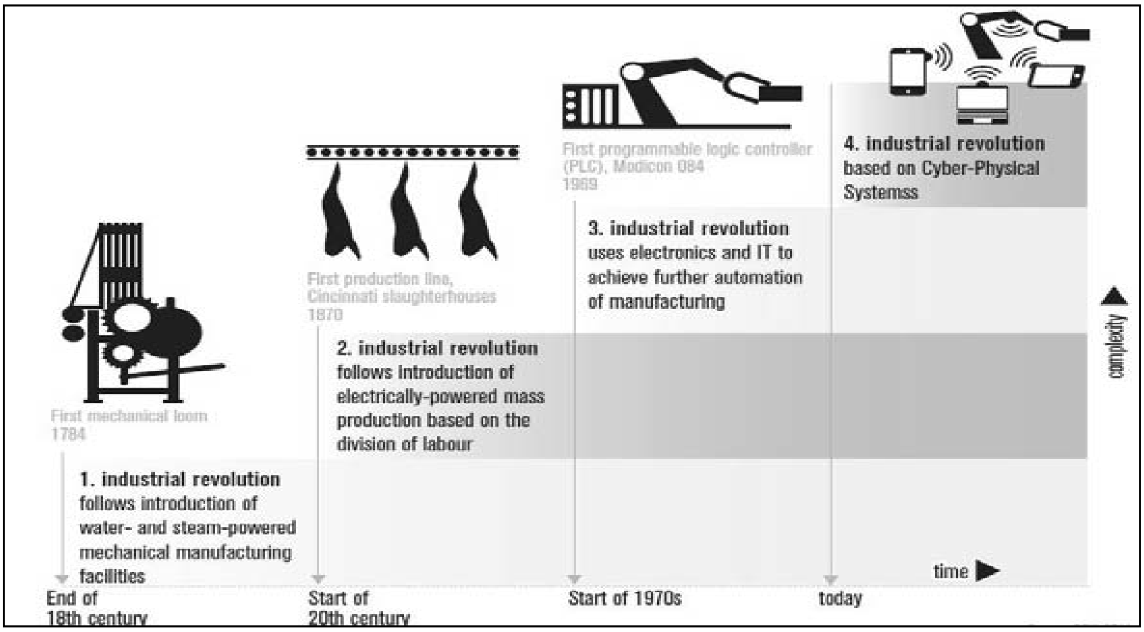

Figure 2. Major milestones of capitalist development. Source: Kagermann et al. (2013).

The speed of technological fields related to Industry 4.0 presents unprecedented historical synergies in capitalist development. These possibilities will be multiplied by emerging technological advances in areas such as artificial intelligence, robotics, Internet of Things, autonomous vehicles, 3D printing, nanotechnology, biotechnology, materials science, energy storage, and quantum computing (Peters, 2017).

Challenges and Opportunities of the Industry 4.0 While a New Tech-Economic Paradigm

One of the great potentials of Industry 4.0 lies in the ability to customize customer demands for reliable production structures. Of course, this type of manufacturing system requires planning and explanatory models that can provide the basis for management for such. In the survey conducted by Schuh, Arnoscht, and Rudolf (2010) with companies, most respondents indicated a high interest in resolving a dilemma between scale and specificity, and to date, the most efficient way has been the introduction of product families between flexibility and mass production). This corroborates the gap in the productive structures to efficiently achieve the desired differentiation of the products produced and the dynamization of time and volumes inherent to the scale production.

Of course, to reach production stages of products that are positioned between flexibility and mass production, it is necessary to involve in a network of high quality all the companies that constitute the value chain of the organization, through a standardized ICT architecture. In addition, underlying aspects, such as trust and security of the information shared in the productive processes are fundamental for the efficiency of this approach (Brettel, 2014).

The effects of this industrial standard also occur on the organization of work, requiring the implementation of a sociotechnical approach that is capable of combining professional opportunities and increasing the responsibilities and competencies required for performance in companies. From the economic point of view, the advanced manufacturing structure, in addition to the potential of the company that implements it, can translate into opportunities for nascent and small businesses with the opportunity to develop and provide services in a top-down stream from the chain to the final consumer (Kagermann et al., 2013).

Notwithstanding the opportunities presented by the introduction of manufacturing systems based on the precepts of Industry 4.0, this approach coexists with a trade-off manifested through the absence of adequate technological infrastructure, specialized professionals, and organizational barriers to provide the processes of Transformation to the new reality (Stich, Kompa, & Meier, 2011).

According to interviews conducted, Schuh et al. (2010) identified in the interviewees an important concern with the aspects related to the quality and safety of customized products, requiring mastery of simulation software and virtual prototyping that allow the performance of tests and simulations each Reality.

Processes for Transforming the Current Industrial Standard for Industry 4.0

Changing is not a trivial task. Making the transition from the current industry standard to the Industry-Standard 4.0 industry standard requires supplanting many variables inside and outside the enterprise.

Delloite (2015) conducted a survey of 40 executives from mechanical and electrical engineering, vehicle manufacturing, and precision instruments companies in Switzerland in 2012 to examine the potentialities and changes required to characterize themselves as a major industry locus World.

When companies were asked whether the IT infrastructure already installed was appropriate to support transformation to Industry 4.0, only 32% said “Yes”. Another 48% said they had at least some elements of prepared infrastructure, while the other 20% said they did not have the proper infrastructure.

Regarding the talents and the number of skilled employees required for this transformation, the companies surveyed were not clear in the answer, precisely because they did not know the framework necessary for the implementation of Industry 4.0. Only 4% of companies said they already have qualified staff, while 80% said they have qualifications, however, for specific areas. Only 16% said they have complete absence of qualifications.

When asked which organizational areas were able to engage more towards the transformation to Industry 4.0, companies indicated R&D activities. On the other hand, areas such as warehousing and logistics and the company’s internal management have made little progress towards the new approach.

Studies conducted by Karlsruher Institut für Technologie (2016) and Geissbauer, Vedso, and Schrauf (2016) were carried out with the aim of guiding the processes of transformation from the current industrial standard to the industry-oriented standard 4.0.

For the Karlsruher Institut für Technologie (2016), the transformation processes for the Industry Approach 4.0 represent profound changes in the design of industrial production, in terms of productivity and flexibility, providing methods and recommendations for the transition, from the objectives to be achieved with the Industry Approach 4.0. These include: diagnosing people, products, equipment, existing and non-existent information systems; development of networking activities; idealization of a virtual “cokpit” of the process; and the development of methods and tools for dealing with the transformation of an existing factory into an intelligent network plant.

The studies produced by Geissbauer et al. (2016) indicate the importance of evaluating the current and desired digital maturity of the company; idealize a pilot project in order to demonstrate the value of the business in light of the Industry 4.0 approach; define necessary resources, including people and technology facilitators; to establish multifunctional analytical capacities, so as to better manage the objectives of the productive processes; establish an industry-driven organizational culture 4.0; and develop partnerships to develop collaborative projects in this perspective.

Research Procedures and Techniques

This work presents an exploratory research, through a case study of the company FESTO AG to examine its processes of transformation from the current industrial standard to the industry standard 4.0. To meet this objective, face-to-face interviews were conducted with the regional product manager for the Americas, from FESTO Brasil, in September and October 2016, as well as obtaining institutional material from the company that was made available during face-to-face interviews.

Inspired by the industrial transformation approaches for Industry 4.0 produced by Karlsruher Institut für Technologie (2016) and Geissbauer et al. (2016), the following analytical framework was developed for the FESTO case:

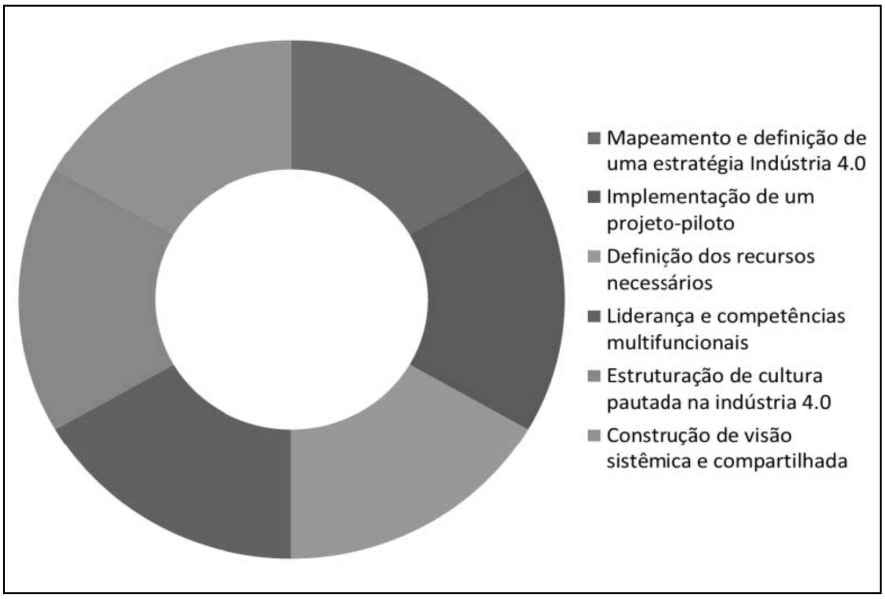

Figure 3. Analysis framework of the transformation processes for the Industry Approach 4.0. Source: Own authorship (2017).

In the framework of analysis of transformation processes for the Industry Approach 4.0 proposed in this paper, it is considered fundamental to gather strategies, skills, resources, and tools to qualify the company from the technological, human, and organizational point of view in the direction of the Industry Paradigm 4.0, which implies that companies are guided by the following assumptions:

Mapping and Defining an Industry Strategy 4.0

It is necessary to diagnose the current production requirements and the current degree of digital maturity vis-à-vis the ideal conditions required for the new industrial standard. It is then necessary to set clear targets for reducing the technology gap in the context of the Industry Approach 4.0 and the ways to achieve those objectives. Underlying this transformation, it is necessary that this transformation be legitimized at the highest level of the company, supporting all the elements that cover the transition path.

Implementation of a Pilot Project

For the transformation process to be efficient, it is necessary to establish a proof of concept in a way that validates the experimental results and is reproduced. For the pilot project that can represent the structure, behavior rules, and intelligent and network production decisions and the basis of network products, equipment, information systems and people. Although the initial scope of the project is small, the end-to-end concept of Industry 4.0 needs to be incorporated into the pilot project, that is, provision of the necessary materials to delivery to the customer (and after-sales services).

Definition of Required Resources

Based on the lessons learned in the pilot project, it is necessary to map in detail the resources needed to implement the integral project in the company (people, products, equipment, and information systems throughout the organization), detecting what is already available in the company and what you need to acquire from professional skills and competencies and agile and functional IT infrastructure.

Leadership and Multifunctional Skills

Another important dimension of the transformation processes for the Industry Approach 4.0 lies in the need to establish multifunctional analytical capabilities, closely linked to the strategic priorities of the whole company. In combination, it is necessary to establish the data interaction of the different functional areas of the company, such as quality data, logistics with engineering functions. Learn to value data through intelligent systems design, using real-time analytics to tailor products to customers and continually improve their processes. Clear leadership of this process is required, with a high commitment and integrated vision of all the interested areas. For this, to develop indicators of performance of the processes inserted in the new industrial context proves to be an important tool to guarantee the integrality of the results.

Structured Culture Structuring in Industry 4.0

In the context of the industry-standard approach 4.0, it is important that company professionals feel the need to think and act within the new technology standards, being willing to experiment, learn new ways of working, and adapt daily processes in that direction.

Systemic and Shared Vision Construction

Industry 4.0 induces the development of products with a relative degree of complexity. Therefore, in the transition to this industrial standard, it is imperative to create partnerships and align platforms to complement product and process development skills in collaboration with actors outside the company, such as universities, partners, suppliers, customers, and other sources of interaction. Accelerate scanning processes.

The Company FESTO AG and the Implementation of the Concept of Industry 4.0

FESTO is an independent family business founded in 1925, based in Esslingen, Germany, but with global business. The company is a provider of pneumatic and electrical automation technology to 300,000 customers in more than 35 industry segments around the world. In addition, the company has a division called Didactic that is responsible for the development of learning, training, and consulting systems. This division is present in all its subsidiaries around the world, which have installed in 61 countries.

In 2016, the company recorded a turnover of € 2.64 million, because of the group's global actions, investing about 8% of this amount per year in R&D. To achieve these results, FESTO has approximately

18,700 employees in the global spectrum and its portfolio has more than 33,000 catalog products and several hundreds of thousands of variants.

FESTO develops approximately 15,000 customer solutions per year, working in the areas of pneumatic, servo-pneumatic, and electrical automation technology, as well as industry-specific skills development solutions and industry consulting.

From the 2000s, the automation market has undergone a process of "commoditization" with many new competitors and reduced prices, leading to a dramatic that of the contribution margin of commodities. In addition to economic factors related to the production and marketing process, FESTO found in the studies produced by consulting firms McKinsey, BCG, and Roland Berger that information-based businesses are transforming the competitive environment worldwide.

The increase in the use of new electronic technologies in the products, miniaturization, and network communication resources allowed the revision of the production concepts used so far, thus creating the opportunity for the design of the new production plant in Scharnhausen to be based on the Industry 4.0.

The Process of Transformation for the Industry Concept 4.0 of the FESTO

Mapping an industry strategy 4.0. Following a strategic planning in 2016, FESTO decided to adapt its plant to the new scenario based on the concepts of Industry 4.0. To do so, we mapped the maturity of the technologies considered as enablers of this new scenario, the possibilities of conversion of the company, and its positioning in the markets in which it operates. This mapping pointed out investment priorities for the development of technologies, products, services, and the production lines themselves in the direction of Industry 4.0.

The interviews revealed that this decision resulted from the need to adapt the production processes to the competitive environment increasingly based on the commoditization of technological solutions in the automation sector, finding in the approach of Industry 4.0 an opportunity to produce intelligent solutions from more flexible production lines and adaptive.

For the transformation process, the interviewee showed that the company opted for the development of the following solutions with a view to the conversion strategy of the company to the Industry 4.0:

(a) Platform enabler: It is the development of products with connectivity characteristics, which enables the communication directly with the Internet, as well as the integration of advanced sensing and diagnostic functions, enabling the generation of useful data for the asset management and predictive maintenance;

(b) Data provider: From the analysis of the data provided by products connected to the Internet, product performance behaviors are observed in the respective applications, allowing for better process adjustments. This data can be provided to customers in the form of remote maintenance and process optimization services;

(c) Service provider: Characterized by the premise of providing automation as a service, where the customer pays for the system's productivity, not for the assets acquired;

(d) Platform provider: It is characterized by the provision of components of multiple control, automation, and management systems, which operate in an integrated manner. It represents the most complex and broad stage of supply, enabling a complete solution for a specific industry.

Implementation of a pilot project. In the implementation of the production plant called the Scharnhausen Technology Plant, inaugurated in 2016, the interviews revealed that the company developed specific approaches for the implementation of Industry 4.0. For the structuring of this plant, FESTO has been involved in several collaborative research projects that deal with various aspects of production based on the Industry 4.0.

Definition of required resources. Institutional materials from the company show that FESTO's strategy is to invest up to 8% of its R&D revenue, creating a culture of research and innovation. This intentional positioning in the advance of the generation of knowledge to new fields allowed greater involvement of the teams of researchers and engineers in multiple projects related to the theme of Industry 4.0.

Based on the results of the gap analysis that compared the strategy for Industry 4.0 with the maturity of current processes, it was possible to identify the need for development and acquisition of new technologies, such as those related to the digitization of productive processes, inclusion of collaborative robots in assembly actions, and systems based on increased reality in production management and maintenance routines.

To this end, R&D projects in Industry 4.0 were included in the company's research project development plan, according to its innovation and technology management process. In this process, trends and opportunities are analyzed and from the priorities, R&D resources are allocated to the projects.

Leadership and multifunctional skills. The term "Industry 4.0" means that the tasks to be performed become increasingly demanding, both technologically and organizationally. Interdisciplinary skills are growing in importance, which is why it is necessary to adapt the skills that are taught to the various trades. As the boundaries between different functional levels become increasingly fluid, the need for adaptation affects all technical professions.

In this context, FESTO, through its teaching division, FESTO didactic, started a technical qualification program for the employees who would join the new production plant in Scharnhausen, near Stuttgart. The trainings were planned and executed in modules according to the personal involvement in the process. Special attention was given to the leaders, who came to play an even more relevant role in harmonizing the new technologies and operators' expectations, which gradually began to receive more responsibility.

Production operators are being prepared to take on management responsibilities for production resources, monitoring machine behavior with support of maintenance systems, predicting unwanted stops, and increasing the availability of assets.

In addition to internal actions, FESTO has developed a portfolio of training aimed at training professionals for Industria 4.0, signing agreements with the Government of BadenWürtenberg to supply laboratories called CP Factory (Cyber Physical Factory), which are being installed in universities and technical schools.

FESTO didactic has developed solutions for teaching the technologies and processes of Industry 4.0, such as:

(a) Cyber-Physics Factory: The Cyber Physical (CP) Factory research and learning platform provides higher education institutions and enterprises with access to the technology and applications of Industry 4.0. The platform demonstrates the future production technology in a locally controlled, intelligent network.

(b) Learning System I 4.0: A continuous learning system, starting with the project workstation I 4.0 and continuing through the CP Lab to the complete CP Factory, the modules and pallets can be used in all stages. The CP Lab can be connected to the CP Factory via the robot Robotino® and the deflector module.

(c) Training and consulting: To establish the 4.0 industry in a company, the training and qualifications of its skilled workers must be adapted to meet the new requirements of this interdisciplinary approach. For example, service technicians not only need practical mechatronics experience, but also knowledge of IT infrastructures so they can work to quickly correct machine downtime.

Structured culture structuring in Industry 4.0. FESTO's strategy for establishing means to enable the development of a culture more suited to the Industry 4.0 environment which was based on the strong qualification of the team present in the Scharnhausen Technology Plant especially regarding interaction with collaborative robots. Naturally, transition to a culture ruled for Industry 4.0 cannot be characterized as a discontinuity of its performance in the field of mechatronics and heavily based on innovation.

In this way, it has been expanded in the teams that operate Scharnhausen Technology Plant values and beliefs associated with FESTO as an important actor in the dissemination of Industry 4.0 in Germany. To a certain extent, the structural and physical elements of the plant are associated with this perspective, as they are modeled on Industry 4.0 as a "mission" for this group of employees, according to the interviews.

Systemic and shared vision construction. For the implementation of the industry-based strategy 4.0, FESTO strongly considered the different perspectives of the transformation process, which are extended to technological reason, but also man-machine interaction and the question of training and qualification.

To prepare for this reality, the company joined Plattform Industrie 4.0—a consortium of political, scientific, and business actors created to develop a uniform understanding of the concept of Industry 4.0 in Germany, together with a space to develop technological standards, with business models and new forms of cooperation.

The interviewee highlighted the positioning of the 4.0 industry approach as a legitimate goal of action in the company's technological and innovative strategies, guided by the company board. As a first step in the transformation of the company to the new scenario, a portfolio of products was developed with a focus on Industria 4.0, aiming to meet the needs and were presented at the Hannover HMI2017 Fair, among them networked valve terminals that allow total configuration of their functions without the need for physical interventions and which are provided with complex diagnostic systems that inform not only the state of vital internal components but also their characteristics of use, making data available for use in trend analysis processes, enabling the premature diagnosis of predictive maintenance failures.

Final Considerations

In this paper, we examined how Industry 4.0 emerges from enterprise manufacturing structures as a new level of management of the organizational value chain, from the ability to customize customer demands to productive structures with reliability. A challenge imposed on the existing productive structures is to achieve the desired differentiation of the products produced and the dynamization of time and volumes inherent in the scale production, placing itself as a dialectic between flexibility and mass production.

Notwithstanding the opportunities presented by the introduction of manufacturing systems based on the precepts of Industry 4.0, this approach coexists with a trade-off manifested through the absence of adequate technological infrastructure, specialized professionals, and organizational barriers to provide the processes of Transformation to the new reality.

Given this scenario, this work examined the processes of transformation of the current industrial standard to the industry standard 4.0 in the company FESTO, in addition to proposing a framework for analyzing the processes of transformation of the current industry standard for Industry 4.0 inspired by the approaches produced by Karlsruher Institut für Technologie (2016) and Geissbauer et al. (2016).

Through the face-to-face interviews and the institutional materials of Festo, it was observed that the company inserted in its strategy of products and innovation the concept of Industry 4.0. To do so, he planned and built a new production plant based on connectivity, sustainability and a collaborative environment, especially between man and machine. To support this orientation, FESTO has strengthened its technological base, culture, training of its productive, commercial, and management teams

This decision resulted from the need to adapt production processes to the competitive environment increasingly based on the commoditization of technological solutions in the automation sector, finding in the approach of Industry 4.0 an opportunity to produce intelligent solutions from more flexible and adaptive production lines.

Among the difficulties encountered by FESTO and indicated in the interview are:

(a) The need to homogenize the understanding of the concept of "Industry 4.0" and of the resulting changes in the technological sphere;

(b) The specialization of interactions with customers, which assume an expanded role under the control and control of specifications and delivery of products, compared to traditional industry;

(c) The technical and economical feasibility for the implementation of the production-based production lines 4.0 in the Scharnhausen plant, due to the lack of scale of production associated with relatively complex processes;

(d) The qualification of workers and managers for more than one year to manage more autonomous teams;

(e) The cultural adaptation of the production system and traditional German management of the teams for a more autonomous and dynamic management;

(f) Harmonization in the relationship with trade unions, which still need to learn about the impact and the consequences for the world of work.

Certainly, the challenge in transformation processes for Industry 4.0 address changes in strategic, organizational, technological, and human domains. For this agenda, the intersection of the agenda of political, scientific, technological, and innovative actors is fundamental to establishing bridges for this new techno-economic paradigm of the 21st century.

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