Chapter

Industry 4.0 - What Is It?

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Abstract

The industry 4.0 is a new industrial model that characterizes the Fourth Industrial Revolution. This advanced manufacturing model is represented by intelligent, virtual, and digital performance in large-scale industries and emerges as a disruption to the three industrial revolutions that occurred before it. The new industrial model itself includes a factory-wide integrated structure and potential technologies in various areas of industry activity, and these technologies are intrinsic to industry 4.0 design principles, which are also responsible for ensuring the innovative performance of this new industry. With this explanatory context, the objective of this paper is to present what is really industry 4.0, its origin, as well as its main characteristics. In this way, knowing what the Fourth Industrial Revolution is, the readers will be able to better understand the content presented in the next chapters about the diverse potentials of the new industry.

Keywords: industry 4.0, Fourth Industrial Revolution, industrial model 4.0, advanced manufacturing, design principles

1. Introduction

The history of the industry since its inception is marked by the acquisition of great knowledge, events, and discoveries that have changed the structure of cities, their populations, the types of products they offer and the way they offer them, innovation in the development of production processes, and the way employees work, among many other aspects.

The industry at the time of its emergence can be verified as a result of the combination of three fundamental aspects: knowledge, experimentation, and entrepreneurial innovation. These aspects have effectively contributed as a potential medium for offering jobs and developing new products to people and their needs.

Thus, the industry has its evolution distributed in different stages and of equal relevance. Such stages are represented by the First, Second, Third, and, imminently, Fourth Industrial Revolution. It would be misleading to say that industry 4.0 is a new model that is totally unaware of the industrial revolutions that occurred earlier. In fact, industry 4.0 fully utilizes all the foundations of previous industrial revolutions, however, with higher rates of integration, digitization, virtualization, technologies, and rapid response times to stimuli.

Just as the industry has undergone many changes and improvements in each of its stages, the products developed, the ways of distribution, the customer demands, the work of people, and the internal and external aspects have changed. Knowing the industry 4.0 and all its capabilities in different areas is essential for the full use of its potential, and also for those looking to achieve a form of collaboration in the new industry, it is important to know all the new opportunities it presents.

In this context, the purpose of this chapter is to introduce industry 4.0 and its main features. For this, this chapter is structured in three next sections, among which the first refers to the historical evolution of the industry, while the second refers to the origin of industry 4.0 and its main understandings, and finally, the third refers to the design principles of the new industrial model.

2. Historical evolution of industry

Considering the combination of the three fundamental aspects that contributed to the emergence of industry, namely, knowledge, experimentation, and entrepreneurial innovation, industrial revolutions could have their consolidation designed. The first aspect, knowledge, refers to the range of understanding of scholars and inventors of decades ago, who researched, investigated, sought possibilities for great new discoveries at the time, and was able to increase their ability to understand and assimilate. The second aspect, experimentation, is the process of making explicit the tacit knowledge of scholars and collaborators, in order to prove and prove possibilities and unfeasibilities. The third aspect, entrepreneurial innovation, is the confidence of employers of the time to believe in and invest in new discoveries, work models, and ways of producing and expanding their business on scales never before imagined.

The industrial revolutions cannot be reported only by inventions or discoveries of energy sources, new machines, materials, or methods. However, these factors are of utmost importance for the development of the economy in the last two and a half centuries. Decades ago machines such as hydraulic mills already existed. However, the spread of these machines, called machinery, characterizes and distinguishes this period from previous periods [1]. **Figure 1** [2] presents the three industrial revolutions that have already taken place with their respective highlights.

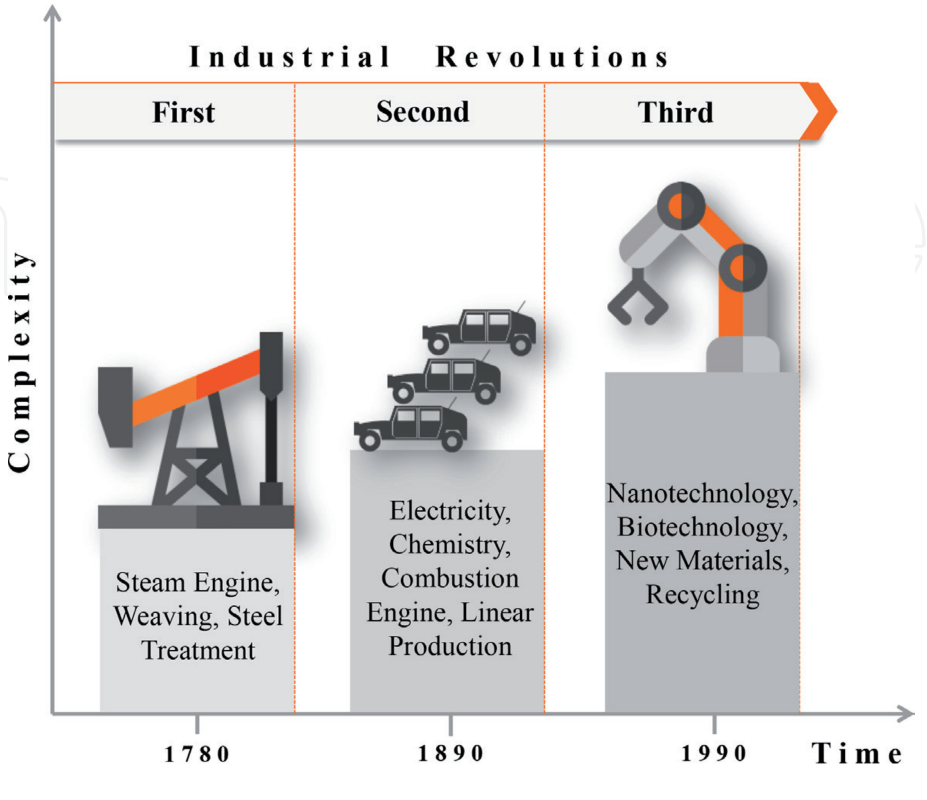

Figure 1.
Industrial revolutions and their highlights. Source: Adapted from [2].

Until the First Industrial Revolution, from the mid-eighteenth century, the sources used were water, animal energy, and wood, which was the main building and combustion material. In construction, iron became one of the most prevalent materials, while coal was the first fuel, and steam one of the main engines, all interacting with each other forming a new technical system at the time [3].

The development of industrial society was observed at three distinct times. The first of these corresponds to the so-called First Industrial Revolution, which was driven by the creation of the steam engine and had as its greatest theorist Adam Smith, who was also the creator of economic liberalism [4].

The First Industrial Revolution lasted until the last decades of the nineteenth century, and during this period significant changes occurred. The factory production has been expanded to countries other than England as well as to other consumer goods segments. The mid-nineteenth century saw the revolution in transport and communications, including the spread of the railways, the telegraph, and transoceanic steamboat navigation in steel hulls. Activities that went beyond borders, which were considered a mixture of enterprise and adventure, are made possible and commercially and financially integrated into the logic of business expansion [5].

After the First Industrial Revolution, the so-called Second Industrial Revolution began in the second half of the nineteenth century, which included a series of developments in the chemical, electrical, oil, and steel industries and also encompassed other key developments during this period like steam-powered steel ships; airplane development; canning of food; mass production of consumer goods; mechanical refrigeration, as well as other preservation techniques; and the creation of the electromagnetic telephone. This era also marks the advent in Germany and the United States together with France and the United Kingdom as potentialities in the industrial environment. In the United States, the Second Industrial Revolution is commonly associated with the scientific management proposal studied and applied by Frederick Winslow Taylor [6].

The transition to the Second Industrial Revolution is consolidated with the inclusion of new sources of raw materials and energy, especially electricity, and increasingly oil. It is at the end of the nineteenth century that a certain cyclical pulse can be seen in the world economy. In the early decades of the twentieth century, the revolution in communications and transport intensified with the spread of the automotive and aeronautics industries, as well as telephony and radio transmissions [5].

In accordance with the statement of the previous authors, the author [1] considers that from the last half of the nineteenth century, it can be affirmed that there was a Second Industrial Revolution. While the former was based on iron and steam power from coal, the latter was based on electricity and steel, providing relevant developments in communications, chemistry, and the use of petroleum. But these innovations, initially and generally, did not fully replace the old ones, so they only began to stand out, as their full realization took place only in the twentieth century.

The Third Industrial Revolution started in the 1970s [7] and characterizes the structuring of capitalism, so the economic system presented cooperation as a new paradigm, arguing that the objectives of an organization can only be achieved together. Given this, there was a high hiring of companies; the development of these happened more and more driven to get strong joints with the same proportion of reciprocity. This third revolution presented a different way of managing the economy, highlighting a more horizontal, more flexible negotiation, where companies come together to achieve more precise and consolidated economic action [8].

The Third Industrial Revolution developed the role of the instrumentation of the financial economy, called the market economy, providing accelerated development in the media and transport, as well as allowing the global integration consisting of globalization [6]. For [7], this revolution was well known for the technologies that were employed in Japan in the mid-1970s, including biotechnology, computer science, Computer Numerical Control (CNC), microelectronics, and telematics integrated system, among others.

3. Industry 4.0: origin and key understandings

The term "Industry 4.0" comes in the context of a new industrial revolution, which emphasizes and includes the latest technological innovations and aids in both fast and customized production. The term originated in Germany in 2011, referring to changes directly linked to automation fields integrated with information technology [9].

With the aim of promoting manufacturing automation and, consequently, increasing productivity through "smart factories," the still imminent Fourth Industrial Revolution can be characterized by the integration between the Internet and production processes, with the aid of smaller sensors and artificial intelligence applied to machines [10].

There are numerous and distinct definitions and nomenclatures for industry 4.0; however, the definition set out in this chapter is that industry 4.0 is an advanced manufacturing model that includes within itself an extensive set of technologies not necessarily unpublished but integrated with each other and with the whole industry which is characterized by its high virtual, digital, and technological performance. The industry 4.0 is still a new industrial model with disruptive characteristics in relation to environmental performance as it is considered a sustainable manufacturing model, as well as human work by offering a set of potential technologies that help the work performed by people in the industry, eliminating aspects such as intense physical effort, and market positioning, as industry 4.0 has an excellent response time to internal and external stimuli.

By 2014 in Germany, industries were already assessing their readiness for industry 4.0 implementation. At that time at least 41% of German companies were aware of the industry 4.0 term and so have started some concrete initiatives. But the road to go is long and some industries still do not know the term. This applies in particular to small-scale industries, where 44% did not know what industry 4.0 is. On the other hand, the new industrial model is well known in larger companies, where only 17% did not know the term. There is also a delay in industry 4.0 implementation plans between large industries and small and medium enterprises (SMEs). Almost 20% of original equipment manufacturers had solid implementation strategies; while there is a huge volume of SMEs in Germany, only 17% were equipped with implementation strategies [11].

According to [12], industry 4.0 is not only a technical challenge but also a reality that will significantly change the organizational structure of companies. Not intended to provide a comprehensive listing, the authors exemplify five visions for disruptive industry 4.0 change:

- New level of socio-technical interaction: Autonomous and self-organized production resources carry out planning processes in value chains between organizations.

- Smart products: The products and the tolerable operating parameter of a certain production process are mutually known. These products can be grouped to optimize production.

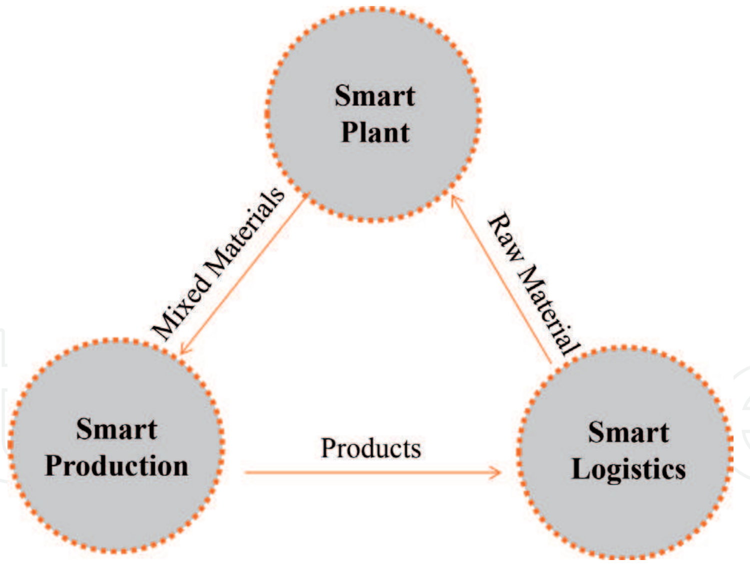

Figure 2.
Key aspects of industry 4.0. Source: Adapted from [13].

- Individualized production: Flexible reconfiguration enables industries to consider the specific characteristics of customer demand and product during design, planning, production, and recycling phase.

- Autonomous control: Employees control and configure intelligent production resources based on targets sensitive to the present context.

- Product design controls product-related data: Product-related data becomes a central feature in managing its product life cycle.

According to [13], industry 4.0 is a junction of three general aspects to consider: smart plant, smart production, and smart logistics. According to [14] the "smart plant" has evolved from the digital factory and is a key component of the smart infrastructure for the future, with an emphasis on highly potential production systems and processes, as well as performing network distribution in production facilities, which constitutes the factory layout. **Figure 2** [13] presents the integration between the three aspects mentioned above.

The "intelligent production," primarily related to industry-wide production logistics management, coupled with human-to-machine (H2M) interaction as well as the application of 3D/4D technology in industrial processes, is a high-capacity industrial chain with a high capacity to be flexible, personalized, and actively maintained in a network. The "intelligent logistics," especially through the Internet and logistics resource integration networks, cooperates with the high performance of logistics resource efficiency on both the supply and demand side, so it is can obtain a service match for logistical support. These three aspects are independent of each other, which with coordination and mutual cooperation constitute the industry 4.0 production system. It is noteworthy that smart manufacturing is the core of this new industry, whose purpose is to create customized products for customers [15].

4. Industry 4.0 design principles

According to [16], the industry 4.0 encompasses six design principles in its framework, which are called decentralization, virtualization, interoperability, modularity, real-time capability, and service orientation. These principles are called "design principles" because they contribute to the design or transition process of a common industry, or 3.0, to industry 4.0.

4.1 Decentralization

The first principle, decentralization, is understood in industry 4.0 as the greater ability of local companies and specific operations, as well as those carried out by machines, to make their own decisions on their own. Rather than using central computers or passing a decision hierarchically, enabling and allowing local operators to respond to changes and readjust, this principle provides more flexibility and makes it easier to use expertise. This can be perceived as a decomposition of the classical production hierarchy for the change of companies as decentralized self-organizations [17].

However, the principle of decentralization cannot be observed only for machines, as it refers to the autonomy granted to people as collaborators in industry 4.0. They have greater freedom to identify aspects, analyze parameters, and carry out decision-making whenever necessary, aiming at the common good for their area of activity in the industry as well as for its fullness.

4.2 Virtualization

For [18], the principle of virtualization is that by using machine-to-machine (M2M) monitoring and communication, a virtual twin can be abstracted from the industry. The sensor data is linked to virtual plant models and simulation models. Thus a virtual copy of the physical world can be created. In case of failure, an employee can be notified. In addition, all necessary information, such as next work steps or security provisions, remains available.

The virtualization in industry 4.0 is used by people as highly potential tools to aid human work. This principle streamlines the time, analysis, and decision-making of employees and established teams by providing, sharing, and synthesizing information virtually, quickly, and in real time.

4.3 Interoperability

The principle of interoperability in the industry 4.0 manufacturing environment is that cyber-physical system (CPS) comprises intelligent machines and intelligent storage systems and facilities capable of autonomously exchanging information, initiating actions, and controlling each other independently. The embedded manufacturing systems are vertically connected with business processes internal to industries, and horizontally, with the value chain, by connecting software and programs [19].

The interoperability is also linked to the work performed with H2M interaction, consisting also in the ability of people to work harmoniously with the machines, so that the committed effort is realized in sync in all industrial activities.

4.4 Modularity

The principle of modularity involves modular systems that can flexibly adapt to changing requirements by replacing or expanding individual production modules, making adding or removing modules much easier. These modular systems can thus simply be adjusted in case of seasonal fluctuations or changes in product production needs, as in the case of including new technologies [20].

Thus, production can always adjust to environmental, systemic, and changing customer demands without error, lost productivity, or customer dissatisfaction.

4.5 Real-time capability

To define the principle of real-time capability, [19] states that in the manufacturing process, intelligent machines with specific software will automatically adapt to the process and decision-making by CPS to the productive needs, thus monitoring the product quality in order to make decisions at every moment of need. This interconnection will minimize misuse of resources, waste, material waste, and increase energy efficiency.

The real-time capability principle is one of the most outstanding aspects of industry 4.0 as it is responsible for ensuring that the industry has the best possible response time to internal and external stimuli by sharing, receiving, and analyzing data and information in real time.

4.6 Service orientation

The principle of service orientation, according to [20], is characterized by the availability, through the Internet, of human, business services, and CPS, which can be used by other stakeholders, facilitating the creation of product-service systems (PSS), also known as product-service. They can be offered internally to and outside the organization.

In this way, industry 4.0 preserves its network performance in partnerships with all its stakeholders, whether customers, partner industries, and suppliers, among many others. Everyone can have access to useful services, products, and information about the industry using virtual and digital platforms available at all times.

5. Conclusion

This chapter presents the context of the historical evolution of industry 4.0, its origin, its main characteristics, and finally the design principles that are intrinsic to the new industrial model. Industry 4.0 is an imminent model of advanced manufacturing that has not yet massively consolidated itself across all industries in many countries. It requires reflection on impacts, analysis of possibilities, and unfeasibilities and practical studies with academic and business partnerships. The potential of the new industry is numerous for all its areas and different segments; its complete transition or implementation requires knowledge and good use.

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