Chapter 11
Trends for Manufacturing Industry: A Strategic Roadmap Toward Industry 5.0

Florin Dragan, Larisa Ivascu, and Ben-Oni Ardelean

Abstract Innovation has led to the rapid development of the manufacturing industry. The future directions of the manufacturing industry will highlight new competencies that employees will have to have and requirements that companies will have to have. The evaluation of these directions and the proposal of some organizational strategies represent necessary elements for the industry, experts and those who want to get started in the production activity. This chapter evaluates the implications of Industry 4.0 and makes an inventory of the technologies used in this industrial era. To consolidate the importance of this revolution for the manufacturing industry, a presentation of the situation in Romania is made from the perspective of various important indicators for Industry 4.0. At the end of the chapter is presented a market research and the strategic roadmap for the future of manufacturing. The case study highlights the fact that companies have a major interest in automation and digitization, but there are also several barriers that must be overcome. These barriers can be overcome with the help of facilitators that are presented at the end of the chapter.

Keywords Innovation · Industry 4.0 · Industry 5.0 · Production · Manufacturing industry · Competitiveness

1 Introduction

Industry plays an important role in local, national, and global development. The current modern industry has gone through several stages of development. The current

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Industry 4.0 appeared in 2011 because of a highly technological project in Germany. The emergence of this concept was based on initiatives to contribute to increasing the competitiveness of German industry. This project promotes computerized production. This advancement of technology has contributed to the improvement of production capacity, efficiency, and loss reduction and contributes to the development of sustainable production systems. Industry 4.0 is also called I4.0 or I4. It is also identified with the Fourth Industrial Revolution. This period can be identified with the digital transformation of production and the creation of the value of processes. The means of production and the different products can be connected, forming networks within which they communicate efficiently, and optimizations are made in real time. The basis of Industry 4.0 is cybernetic systems. Industry 4.0's main goal is customized mass production using process automation and computerization, with cost-effective costs and shorter life cycles [6, 15, 44].

These systems contribute to the development of intelligent factories. Now, production models can be customized, service services can be adapted to customer needs, production system inefficiencies are reduced, the costs of intermediaries in supply chains can be reduced, and irrelevant costs are eliminated. Industry 4.0 focuses on the customer and appreciates the speed, efficiency, and development of innovative services demanded by the market [24, 30, 45, 52].

Most manufacturers should embrace this industrial revolution to maintain their competitive capacity in an extremely competitive market. Fully digital production is the basis of a well-developed strategy that must be based on the principles of action of I4.0 and anticipate the following market and technology requirements [21, 30, 43, 45].

This chapter aims to make an inventory of the evolution of Industry 4.0, then continues with key technologies and applications I4.0. The next part of this chapter covers the market and operational challenges. Because, at present, steps are being taken for Industry 5.0, this chapter presents the possible characteristics of Industry 5.0. At the end of the chapter, it presents a case study referring to the situation of Romanian companies regarding Industry 4.0. Finally, the strategic roadmap for the future of manufacturing is presented.

2 The Evolution of Industry 4.0

The Industrial Revolution 4.0 presents a series of stages of development starting with the 1780s. For over 240 years, the first three industrial revolutions took place which were marked by important stages for the development of production capacity. In 1780, production was mechanized. This stage was an important one for production, representing the basis of the evolution of today's revolution so important for the business environment. At this stage, the manual work of our ancestors begins to be mechanized, being a first step in developing the capacity for globalization. The next stage is that of electrification, starting with the period 1870–1880. It can be seen that the second industrial revolution appeared after about 90–100 years [2, 14, 25, 53].

Fig. 1 History of manufacturing (from Industry 1.0 to Industry 5.0)

The second revolution was the one that led to the realization of the first assembly line, the mass production is realized and, in the production, the electric current is used. It is an important step for today's digitalization that consumes a significant amount of electricity. The third revolution of industrialization knows the third stage, that of computerization and automation of production processes. This revolution occurs in the period 1969–1970. It is an important step in consolidating the basis for digitization and the use of various technologies. In this era of transformation, robots began to be used to perform various man-made activities. The next industrial age, industry 4.0 is called the era of cyber-physical systems (CPS) [5, 29, 40, 50]. CPS includes systems that are capable of autonomously changing the amount of information, launching activities, monitoring, and controlling. The entire exchange of information is based on the Industrial Internet of Things (IIoT). IIoT connects thousands of sensors and transfers data to a local or cloud server to develop predictive models based on this available data [14, 33]. This complex analysis contributes to the decisional industrial system that contributes to the increase of the industry's competitiveness, to the improvement of the industrial processes, of the logistic chain and to the management of the life cycle of the products. Evaluating the elements presented above, it can be seen that there is an important difference between Industry 3.0 and Industry 4.0 [11, 12, 25]. In simple terms, Industry 4.0 is based on machines that operate autonomously without human intervention or presence. The machines used in industry 3.0 can be used in Industry 4.0 if they are updated and are able to exchange data using IIoT and related sensors. Figure 1 shows an evolution of the history of manufacturing, starting from industry 1.0 to Industry 5.0. Industry 5.0 represents the next, anticipated stage of the production industry, based entirely on human absence and automation and connection of machines [17, 27].

3 Key Technologies and Application for Industry 4.0

The technologies used for the development of some applications used in industry contribute to the improvement of the production activity and support the decisional process of the enterprise. Today, more and more complex technologies are being implemented. These technologies connect people with systems, communicate, and generate very good results. Production activities are improved, and organizational

activities are streamlined. These systems can exchange data, communicate, and detect errors independently and with minimal human input. Industry 4.0 presents a series of key principles that contribute to its intense and appropriate use [4, 36, 41, 49].

- Interoperability—is a very important feature for a production system. This feature refers to the ability of a system to exchange data with other systems and to have the ability to use that data. The interoperability feature offered by the present industrial revolution represents a solid support for the present needs.
- Information transparency—this feature provides operators with useful information for the decision-making process. These data can be used in the activities of the production process and in the decision-making system of the enterprise.
- Technical assistance—the human factor in Industry 4.0 no longer has the role of operator, but to solve certain problems that may arise and to make appropriate decisions.
- Flexibility—Industry 4.0 has increased flexibility and thus can improve the company's ability to meet customer requirements and improve the productivity of production systems. Artificial intelligence and cloud computing offer increased flexibility for production systems.

There are a number of key technologies that characterize Industry 4.0. Each technology develops or contributes to the efficiency of production processes and thus a series of benefits for the enterprise are registered. Table 1 systematizes a selection of technologies used in the fourth industrial revolution, that of automation and computerization [28, 32, 38, 46, 54].

4 The Market and Operational Challenges

In the conditions of digitalization of the manufacturing industry, an evaluation of the market requirements is required. These changes not only have several implications regarding raw materials, labor regulations, organizational risk management, global competition, global competition, and globalization but also changes related to transport, market volatility, and price reduction according to demand market. All these changes are shown in the map in Fig. 2 [20, 38, 39, 47].

The new industrial revolution requires operational and market changes. These operational changes are influenced by digitization, automation, and globalization. From the perspective of operational changes, the main changes aim at the involvement of many organizational departments; one of the operational changes refers to the increase in productivity. Each organization wants an increase in production capacity, but this increase must be proportional to the response to market demand, the efficiency of the customer control system and improved communication with suppliers [39]. What is clearly defined is that manufacturers in the industry will invest in digital technologies and advanced manufacturing systems. The acquisition of new capital equipment requires an analysis of the cost–benefit ratio. An efficient acquisition will contribute to the improvement of the production capacity. Among the priorities

Table 1 Key technologies for industry 4.0

Technology	Industry 4.0
Augmented reality (AR)	It is a central part of Industry 4.0. Allows access to digital information. This information can overlap with the physical world
Automation and industrial robots	Automation and industrial robots are the defining elements for Industry 4.0. This digital revolution is characterized by automation and computerization, i.e., these aspects
Additive manufacturing (AM)	This industrial stage is characterized by flexibility, efficiency, and automation. Independent production systems are implemented that require minimal human intervention. This led to the emergence of smart factories and AM. AM is characterized by the fact that the final product can accept the addition of additional layers of material. This reduces the amount of waste and scrap, the production time is reduced, costs are reduced, and the digitalization of business is accentuated
Simulation and modeling	Existing modeling and simulation techniques are important for Industry 4.0. Through these activities, an efficiency of the production systems and an improvement of the costs are achieved. SE speaks in the literature of over 15 modeling techniques used mainly
Cyber-physical system (CPS)	CPSs are physical entities activated on the Internet, in-corporate with various computers, sensors, control components, and other elements. This unit can generate useful information for the production process, to communicate and to carry out the self-monitoring process
Semantic technologies	Interoperability between automated systems can be deficient and that is why semantic technologies are used
Internet of things (IoT)	It is one of the technologies that underlies Industry 4.0. This technology refers to the connections between different physical objects, such as production machines, sensors, or the Internet
Internet of service (IoS)	It plays an important role for Industry 4.0 along with IoT and CPS
Internet of people (IoP)	It involves the digitalization of employee relations, forming a collective intelligent network that stimulates communication using digital devices, the Internet, and data sharing
Internet of data (IoD)	A complex network concept composed of IoT entities
Cloud computing	Contributes to improving the flexibility of production systems

(continued)

Table 1 (continued)

Technology	Industry 4.0
Big Data analytics	Big data analytics play an important role and are used in smart factories and other production systems. For example, production machine sensor data is used to identify maintenance and upkeep periods. This will make the production process more efficient
Blockchain	Blockchain can provide information about the product, distribution, components, subcomponents, and its assembly. In this way, an improvement of the quality is achieved
Cybersecurity	It is a key element for Industry 4.0 because all businesses are exposed to risk of attack. The multitude of things connected at this stage requires security and safety, reliability, and a stable decision-making process
Cognitive computer	Using cognitive computers simulates different computer models based on human thinking to obtain answers to ambiguous and uncertain situations
Enterprise resource planning (ERP)	It is a business process management tool that is used to manage enterprise information

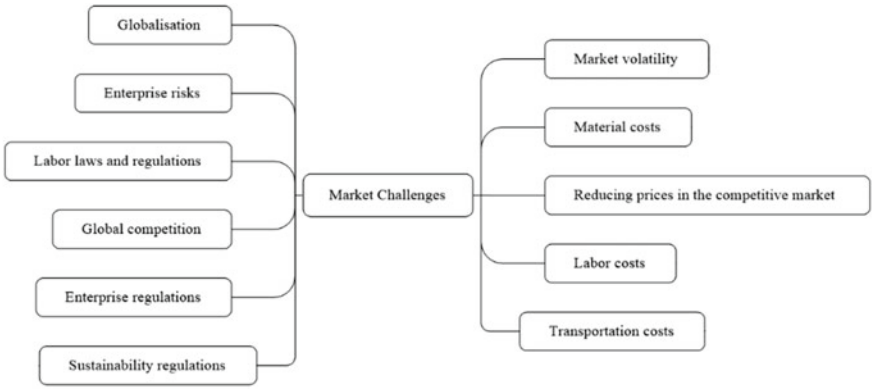

Fig. 2 The market challenges

of production managers are investments in improving collaboration, more efficient communication, a non-polluting and efficient supply system, operational visibility, competitive strategic execution, flexibility, and several dimensions regarding the marketing function [3, 6, 16, 18, 44, 45, 52]. All these technological improvements are presented in Fig. 3.

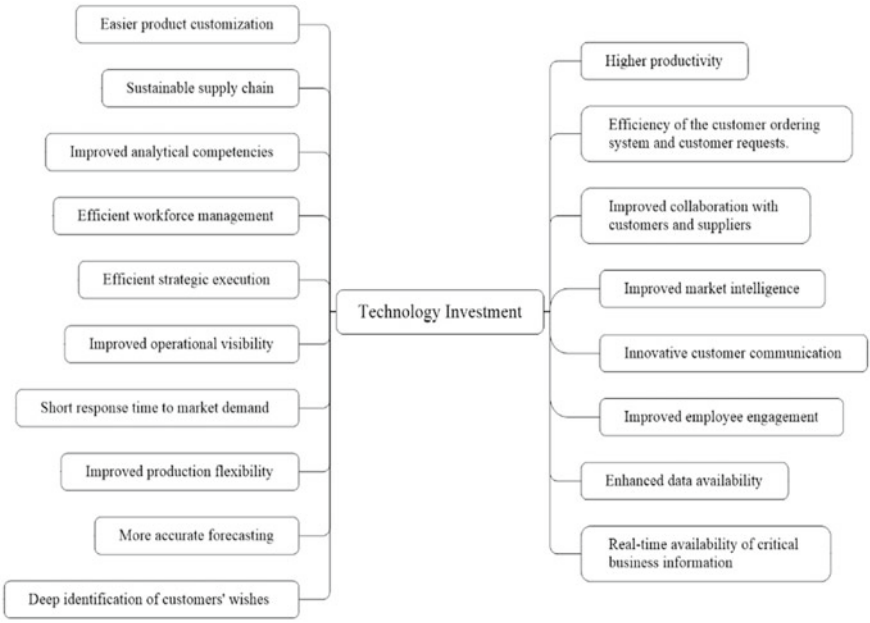

Fig. 3 Operational changes and investments in technology

5 From Industry 4.0 to Industry 5.0 in the Sustainable Development Context

We are currently in the era of digitalization and automation in which we want mass production to be customized, and the resources used to be efficient. In the dynamics of information technology, we try to identify the stage of future development. Industry 4.0 combines the real world with "virtual twins". Industry 5.0 is defined by: human-centric, sustainable, and resilient. If we are currently talking about digital manufacturing, in the context of Industry 5.0, we are talking about digital society [13, 18–20, 34, 42].

Industry 5.0 will aim to eliminate commercial workers from the manufacturing industry. In addition to this central element, new technologies will be developed that will contribute to the substantiation of the concept. These new technologies must be adopted and implemented in accordance with the principles of sustainable development. The 17 objectives of sustainable development must be addressed and respected. The question is often asked whether information technology contributes sustainably to sustainable development or consumes organizational resources and does not contribute to sustainable development. The answer to this dilemma is complex and depends on many factors. So far there are a number of visions and interpretations. The sensors used in the network will be able to contribute to reducing the amount of

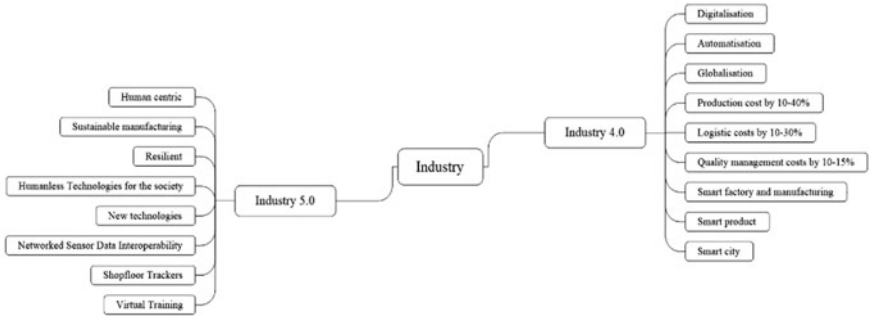

Fig. 4 Industry 4.0 and industry 5.0

data transferred and communicated. Shopfloor Trackers will help track production and associate customer orders [4, 13, 23, 26, 37, 47, 48, 51].

Virtual Training is an opportunity for training and reduces the costs associated with these activities. Figure 4 shows the map of the elements that define the two industrial revolutions Industry 4.0 and Industry 5.0 (future requirements) [7–9, 48].

6 Industry 4.0 in Romania

To emphasize Romania's ability to adapt to the principles of Industry 4.0, a series of data series are presented below. The data series were obtained from the National Institute of Statistics in Romania [22]. To emphasize this capacity, certain dimensions were used, selected according to their importance, as follows: High speed Internet, companies in the industry (investments, financial indicators, number of employees, net investments), European strategy on production customization, employee competencies and higher education in the field, and grants programs. Romania has the capacity to absorb support programs, but the absorption rate can be improved. The analyzed period is 2015–2020. From Industry 4.0 perspectives, Romania has several advantages [6, 35, 43, 55].

- *High-speed Internet*

Romania is among the countries with good broadband internet connection. In a ranking (xxx), Singapore ranks first with about 200 Mbps, Hong Kong ranks second with 180 Mbps, and Thailand ranks third with 160 Mbps. Romania ranks fifth with 152 Mbps, thus having the potential for connections and data transfer in industry.

- *Manufacturing industries*

Table 2 presents the situation of selected indicators for manufacturing enterprises. These indicators are presented for the period 2015–2019. It can be observed that the number of employees, the number of enterprises, and most of the selected indicators

Table 2 The situation of selected indicators for manufacturing enterprises [22]

Dimension	Unit	2015	2016	2017	2018	2019
Number of enterprises	No	48,405	48,349	49,837	52,449	53,123
Average number of employees	No	1,192,380	1,196,306	1,207,044	1,196,882	1,200,011
Average number of people employed	No	1,203,212	1,209,753	1,215,909	1,206,653	1,212,132
Staff costs	Euro	8,233,609,149	9,279,351,952	10,916,174,841	11,571,845,289	1,157,206,555
Salary expenses	euro	6,718,222,850	7,562,620,674	8,895,971,590	11,190,064,600	11,202,309,089
Fiscal value	Euro	66,551,836,735	68,885,918,367	78,184,897,959	85,613,061,224	85,722,448,980
Exercise production	Euro	60,900,612,245	63,310,408,163	72,291,632,653	79,407,959,184	79,594,489,796
Gross value added at factor cost	Euro	13,932,684,717	15,527,444,211	17,475,309,804	4,148,269,000	18,997,324,340
Gross operating surplus	Euro	5,699,075,568	6,248,092,259	6,559,134,963	37,447,959,184	7,527,643,743
The gross result of the exercise	Euro	3,154,970,238	3,550,572,915	3,345,648,685	4,148,269,000	4,150,226,946
Direct exports	Euro	3,1063,265,306	31,557,551,020	36,027,959,184	37,447,959,184	37,650,000,000
Net investments made	Euro	3,388,992,050	3,405,861,544	4,017,730,107	4,329,630,302	4,330,448,873
Gross investment in tangible assets	Euro	5,225,714,650	5,247,141,537	6,594,000,484	6,734,141,622	6,736,182,063

Table 3 Net investments made in Romania and in the manufacturing industry [22]

	Year (million Euro)				
Dimension	2015	2016	2017	2018	2019
Total	20,181.23	19,625.09	18,580.72	20,755.61	24,610.49
Manufacturing industry	3490.67	3454.84	4030.55	4482.76	4629.04

show a favorable evolution for the analyzed period. This underscores the ability of the manufacturing industry to adapt to the requirements of Industry 4.0 and future industrial developments if there is government support to innovate.

Net investments in the manufacturing industry are increasing during the analyzed period. It can be seen in Table 3 that investments increased in the analyzed period 2015–2019. In the manufacturing industry, the increase of investments takes place annually and presents a favorable evolution for the new technologies that can be used and for the increase of the innovation level [10, 31, 43].

- *European strategy on production customization*

The European strategy that also applies to Romania provides regulations and procedures for increasing the national capacity to customize production. Given the situations presented above, it can be stated that the country has the capacity for innovative development, graduates with higher education are growing, the number of enterprises in the manufacturing industry is growing, and financial indicators are favorable for this approach.

- *Employee competencies and higher education in the field*

Table 4 shows the evolution of the number of graduates in the period 2015–2019. In 2015, it is the highest level of graduates. In the period 2016–2017, there is a decrease in the number of employees, following the period 2018–2019 to bring an increase in the number of graduates on the assessed levels. Therefore, at the Romanian level, there is a potential for the development of adequate Industry 4.0 competencies and

Table 4 Graduates at different levels in the period 2015–2019 [22]

Dimensions	Year				
	2015	2016	2017	2018	2019
Total graduates on all levels	557,418	498,889	497,632	501,802	503,086
University education—graduates with a bachelor's degree	85,028	80,815	80,035	82,848	83,210
University education—graduates with a master's degree and postgraduate education	44,458	38,713	39,327	41,580	39,629
University education—graduates with a diploma—doctorate and advanced research postdoctoral programs	3,992	2,260	1,888	1,843	1,920

future industrial revolutions because of the graduates' interest to pursue forms of studies in the country.

The number of employees in Romania experienced a significant decrease during the analyzed period 2015–2019. In 2015, the number of employees is 1248.1 thousand of employees and, in 2019, it is 12198.3 thousand of employees. The number of employees in Romania are presented in Fig. 5.

The employment rate is calculated as the ratio between the civilian employed population and the labor resource, being expressed as a percentage. In 2015, the employment rate of human resources is 66.8 and, in 2019, the employment rate of human resources is 69.6 (Fig. 6).

The number of employees in Romania is presented in Table 5. In the analyzed period 2015–2019, the number of employees increased from one year to another. In 2015, there were 5,041,186 employees, of which 1,433,610 are employed in industry. It is observed that a percentage of 28.5 works in industry. The year 2019 registers an

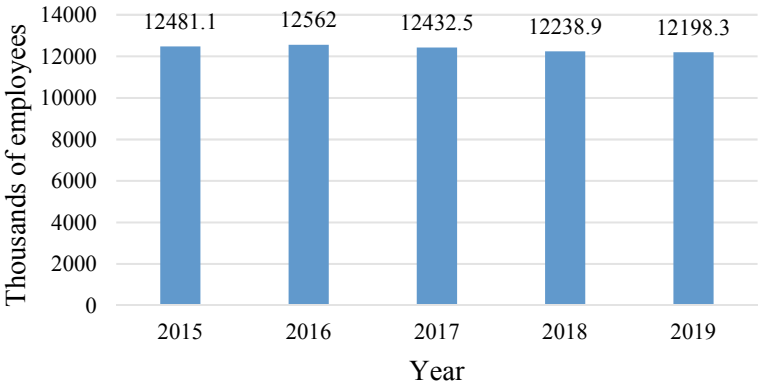

Fig. 5 Labor resource in Romania [22]

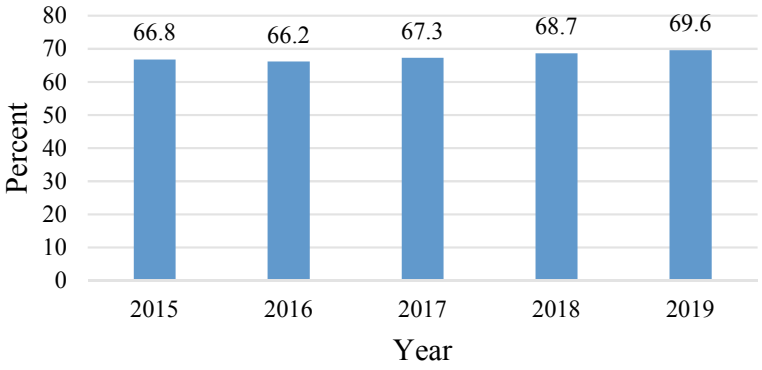

Fig. 6 Human resources employment rate [22]

Table 5 The situation of the number of employees in Romania [22]

		Year				
		2015	2016	2017	2018	2019
Total		5,041,186	5,223,767	5,362,346	5,426,272	5,481,143
From which	Male	2,653,507	2,744,962	2,804,590	2,837,523	2,841,193
From which	Female	2,387,679	2,478,805	2,557,756	2,588,749	2,639,950
Industry		1,433,610	1,459,873	1,498,425	1,486,020	1,455,690
From which	Male	802,209	816,402	837,404	828,245	812,504
From which	Female	631,401	643,471	661,021	657,775	643,186

increase of 9% of the number of employees compared to 2015. At the level of the same year, the number of employees in the industry is higher by 1.5%. This supports the idea that Romania has the capacity to adapt to the new technological approaches that are being implemented in companies because the number of employability requests has increased.

7 Case Studies: Industry 4.0 in Romania

This section presents the situation regarding Industry 4.0 in Romania. An online questionnaire was applied for companies from different fields. The 30 most important companies were selected (based on the public image, financial results, competitiveness level, digitalization, and employee competencies). The research was applied online in 2020. Below is a selection of the results obtained. Figure 7 presents present the technologies used by the responding companies. Each company was able to select at least three technologies used. There is a distribution of technologies used, among

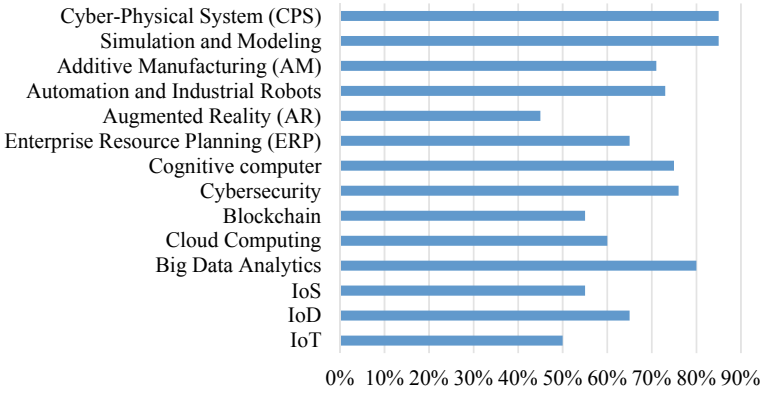

Fig. 7 The three most important practices in industry 4.0 [22]

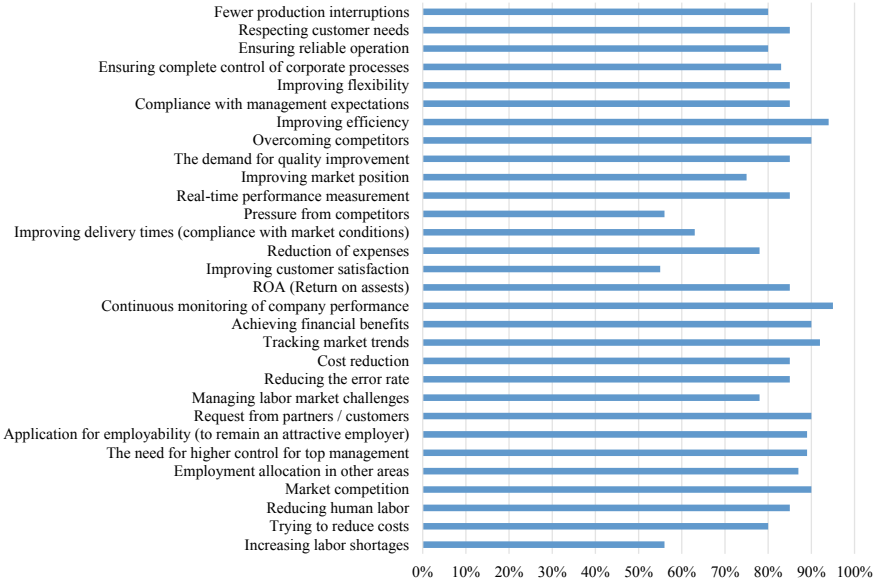

Fig. 8 The facilitators of industry 4.0 [22]

the most used being CPS, simulating and modeling, big data analytics, cognitive computer, cybersecurity, AM, robots, and ERP.

In order to investigate the opinions of the respondents regarding the facilitators for Industry 4.0, Fig. 8, the following attributes were used which were evaluated: increasing labor shortages, trying to reduce costs, reducing human labor, market competition, employment allocation in other areas, the need for higher control for top management, application for employability (to remain an attractive employer), request from partners/customers, managing labor market challenges, reducing the error rate, cost reduction, tracking market trends, achieving financial benefits, continuous monitoring of company performance, return on assets, improving customer satisfaction, reduction of expenses, improving delivery times (compliance with market conditions), pressure from competitors, real-time performance measurement, improving market position, the demand for quality improvement, overcoming competitors, improving efficiency, compliance with management expectations, improving flexibility, ensuring complete control of corporate processes, ensuring reliable operation, respecting customer needs, and fewer production interruptions. Respondents were able to select one or more attributes [1]. Among the most appreciated attributes are the attributes related to the labor force, the improvement of the image, and the productivity.

To identify implementation barriers, Fig. 9 the following barriers were used: lack of necessary skills within the company, lack of financial resources, lack of skilled labor, lack of managers with adequate skills, longer learning periods (employee training), lack of willingness to cooperate (at the level of the supply chain), lack

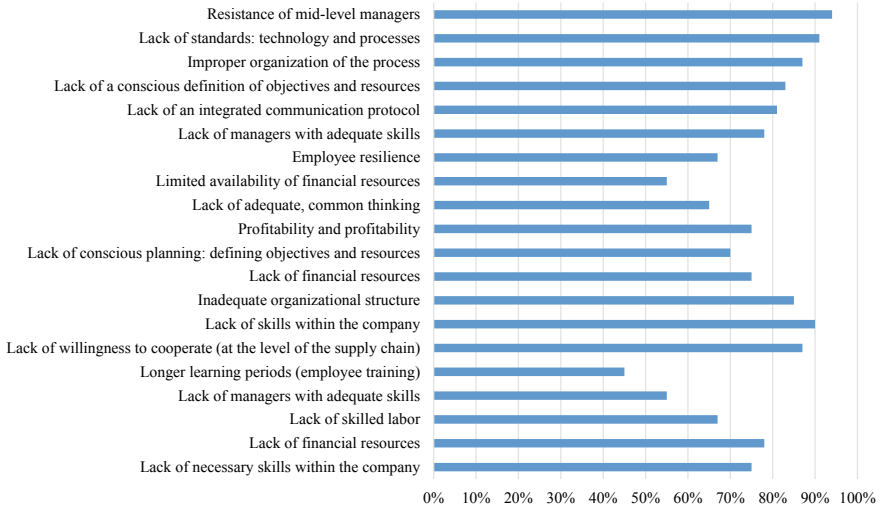

Fig. 9 The barriers of industry 4.0 [22]

of skills within the company, inadequate organizational structure, lack of financial resources, lack of conscious planning: defining objectives and resources, profitability and profitability, lack of adequate, common thinking, limited availability of financial resources, employee resilience, lack of managers with adequate skills, lack of an integrated communication protocol, lack of a conscious definition of objectives and resources, improper organization of the process, lack of standards: technology and processes, and resistance of mid-level managers.

8 The Strategic Roadmap for Future of Manufacturing

The decision-making process for intelligent manufacturing must be efficient and resilient. It must consider all the principles of sustainable development and be based on a series of principles presented in the figure below. It must also be based on the future directions of Industry 5.0 which are presented on the left side of the map. All the strategic aspects of the map are presented on the right side, including the return of personalized production, fast and cheap customization of products, investments in productivity by prioritizing activities and smart decisions. Figure 10 represents a strategic roadmap for future manufacturing.

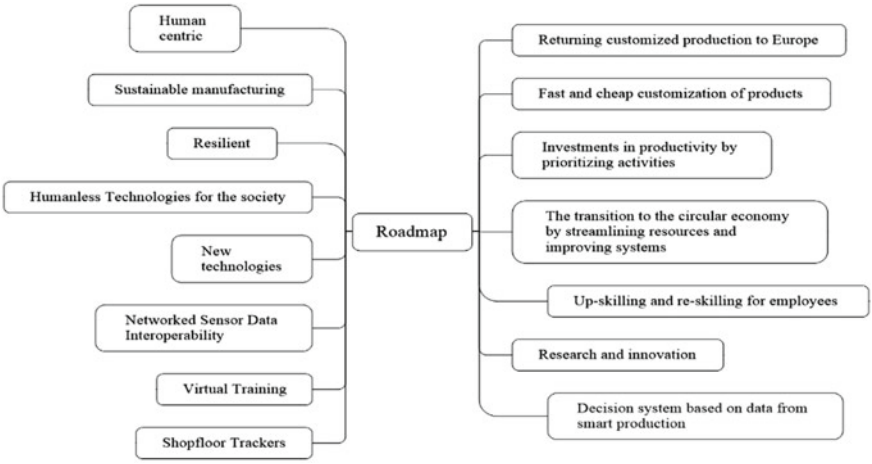

Fig. 10 The strategic roadmap for future of manufacturing

9 Conclusions

It can be concluded that Industry 4.0 is a challenge for many companies. This industrial revolution brings a series of benefits to organizations. In the implementation of this approach, a series of barriers can be identified that pose from competences to the barrier to change. This I4.0 can be characterized by digitization, automation, and globalization. Steps are being taken for the next industrial revolution which will be characterized by independent processes in which human intervention is very low.

Adopting these approaches is important for some industries, but many organizations do not have the resources to fully digitize or automate. These aspects depend on several factors: organizational resources, company size, and much more.

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