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INDUSTRIAL ECOSYSTEMS AS A CATALYST OF ECONOMIC DEVELOPMENT AND GROWTH IN THE FRAME OF INDUSTRIAL REVOLUTION 4.0

Abstract: *The industrial revolutions have generated a lot of progress in production, distribution and service systems. New developments in sales, service, and manufacturing have been achieved due to the significant changes in the information technologies and the synergy brought by European integration. These advances have increased productivity and have greatly improved the industrial background. In recent years, production companies and service structures have faced significant encounters because of the need to coordinate and implement innovative models such as social networks, the Industrial Internet, Integrated Systems (Cyber-Physical Systems), robotics, cybersecurity, data analysis, artificial intelligence, and cloud computing. These new technologies, fused in the term Industry 4.0, declared by the German government as one of the basic advantages for the economic growth strategy, have led to the expansion of the revolution in production and information technology. In consequence, Industry 4.0 is characterized by superior production systems, new communication, sales, and service models. On the other hand, the principles for assessing the transformations in Industry 4.0 are still unreliable, and the structured and systemic application of these technologies in national economies for many countries is not fully achieved. In this study, we propose to examine the conceptual framework of industrial ecosystems as a new concept of development and economic growth within the Industry 4.0' achievements.*

Key words: *artificial intelligence, entrepreneurial ecosystem, Industry 4.0, industrial ecosystem, operational ecosystem, technological ecosystem, people ecosystem.*

JEL: *M11, M15.*

1. Introduction

The term Industry 4.0 has recently been widely applied in manufacturing. After the first industrial revolution, caused by the discovery of the steam engine, the following radical industrial changes came with the implementation of digital machines, and artificial intelligence, with significant productivity effects. The main triggers of radical changes are the individualisation of demand, the efficiency of resource management, optimization of production processes without excluding ecological problems from the equation. Thus, enormous developments such as Web 2.0, applications, smartphones, laptops, 3D printers create great potential for development and economic growth.

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Industry 4.0 has a significant place in the strategy of capitalizing on the opportunities for digitization of all manufacturing steps and service systems. The fourth industrial revolution is achieved by a mixture of numerous physical and digital technologies such as artificial intelligence, additive production, cloud, databases, robotics, augmented reality, and the Internet of Things (IoT). Regardless of trigger technologies, the main purpose of industrial transformation is to rise the efficiency and productivity of resources to increase the competitiveness of manufacturing companies. The transformation we now live differs from previous revolutions by not only ensuring the change of the main models and processes of production but also revealing intelligent and innovative concepts united in a system to create business models based on the first on the satisfaction of consumers' requirements.

The digitization of production processes is on the agenda of many companies around the world. However, most business leaders do not comply with the digital challenges and opportunities or the conceptual leap they represent. Unlike Industry 3.0, which involved automation of machines and processes, Industry 4.0 includes the digitization and integration of value chain data: offering digital services and products operated by physical and virtual physical assets, transforming and integrating all internal operations and activities, building partnerships and optimization of the activities faced by customers. The Industry 4.0 concept requires a deep understanding and management commitment building viable industrial ecosystems and a clear strategy for their development.

In this context, the study in question aims not only at examining the tools and applications of Industry 4.0 but also proposes a conceptual framework for the digitized industry – industrial ecosystems as a business model for companies that want to follow the directions of digital transformation on their way to development and success.

2. Industrial Ecosystem Concept as a Type of Entrepreneurial Ecosystem

The concept of entrepreneurial ecosystem refers to the collective and systemic nature of the entrepreneurship. New companies appear and develop not only on the initiative of "heroes" with visions and entrepreneurial skills. New companies also appear to be in an environment or "ecosystem" of private and public actors who support them, creating a favorable entrepreneurial environment, for example, the existence of previous businesses, the availability of initial funding mechanisms, a system of patents and a regulatory framework that facilitates the creation of new companies. At the same time, the ecosystem may prevent companies from developing as corrupt companies, or if an entrepreneur tries to introduce innovation into production when there is still no technical standard.

The concept of the entrepreneurial ecosystem was first defined by Moore as an economic community supported by a foundation of organizations and individuals interacting – business environment bodies [Moore, 1993]. The economic community produces valuable goods and services to customers who are themselves members of

the ecosystem. The member bodies include suppliers, manufacturers, competitors and other stakeholders. Over time, they correlate with their capabilities and roles and tend to align with the directions established by one or more central companies. Companies that have leadership roles may change over time, but the ecosystem leader is being assessed by the community as it allows its members to move towards common visions to align their investment and support each other.

Moore has used more ecological symbols, suggesting that the company is surrounded in a business environment, that it has to cooperate with other companies and that "the special niche of a business is caused by new species", that companies need to take initiative in developing mutually beneficial relationships with customers, suppliers and even competitors.

The use of ecological metaphors to describe the structure of a business is frequently met, particularly in information technology (IT). For example, J. Bradford DeLong, wrote that "business ecosystems" describe "the model of launching new technologies that came out of Silicon Valley." [DeLong, 2000]. It defines the entrepreneurial ecosystem as "a more productive set of processes for the development and commercialization of new technologies". Many other authors have supported this approach.

According to D. Isenberg, an entrepreneurial ecosystem consists of several elements that can be gathered into six areas: a favorable culture (e.g., risk tolerance, social status of the entrepreneur); tax and regulatory facilities, research infrastructure (e.g., tax incentives, industrial clusters); the availability of special funding (e.g., business angels, venture capital, advantageous credit system); relevant human resources (e.g., skilled labor force, entrepreneurship training programs); and a broad set of institutional and infrastructure support (e.g., legal and accounting advisors, transport and telecommunication infrastructures, entrepreneurship promotion associations) [Isenberg, 2010]. Based on this definition, governments can assess whether they have a durable entrepreneurial ecosystem and what actions they should implement, knowing that each entrepreneurial ecosystem is unique and all elements of the ecosystem are interdependent. Examples of successful entrepreneurial ecosystems can be considered as Shockley, Fairchild and HP, which helped create Silicon Valley or Digital Equipment Corporation, which helped create the Boston Group.

The absolute model of a successful entrepreneurial ecosystem is the renowned Silicon Valley, with its numerous high technology companies and leaders in the field of digital innovations and products. The development of forceful entrepreneurial ecosystems is currently one of the objectives pursued by the European Commission, within the "Entrepreneurship 2020" action plan, that suggests "creating an environment in which entrepreneurs can flourish and grow through better access to funding, in crucial phases of their life cycle, lighter business transfers or clearer and simpler regulations".

In our view, the industrial ecosystem is a form of the entrepreneurial ecosystem specific to the manufacturing industry, which meets all the characteristics of an entrepreneurial ecosystem. Under the conditions of Industrial Revolution 4.0,

the use of the term industrial ecosystem is more current and more concrete. Because, by its definition, the industrial ecosystem comprises several subsystems, such as customer service, technological and operational potential, human potential, which exists individually and correlates with each other due to new information technologies. This concept and its component elements will be examined in the following chapters.

3. Industrial Ecosystem Model

The concept of the industrial ecosystem as a business model under the conditions of the Industrial Revolution 4.0 was introduced by a group of international experts in the PwC Strategy & Global Studies Operations Study, 2018. Thus, the industrial ecosystem is defined as a subsystem complex that targets the key component activities of a producing company. The authors [Geissbauer et al., 2018] have identified four under the basic ecosystems that correlate between the digital instruments form an industrial ecosystem.

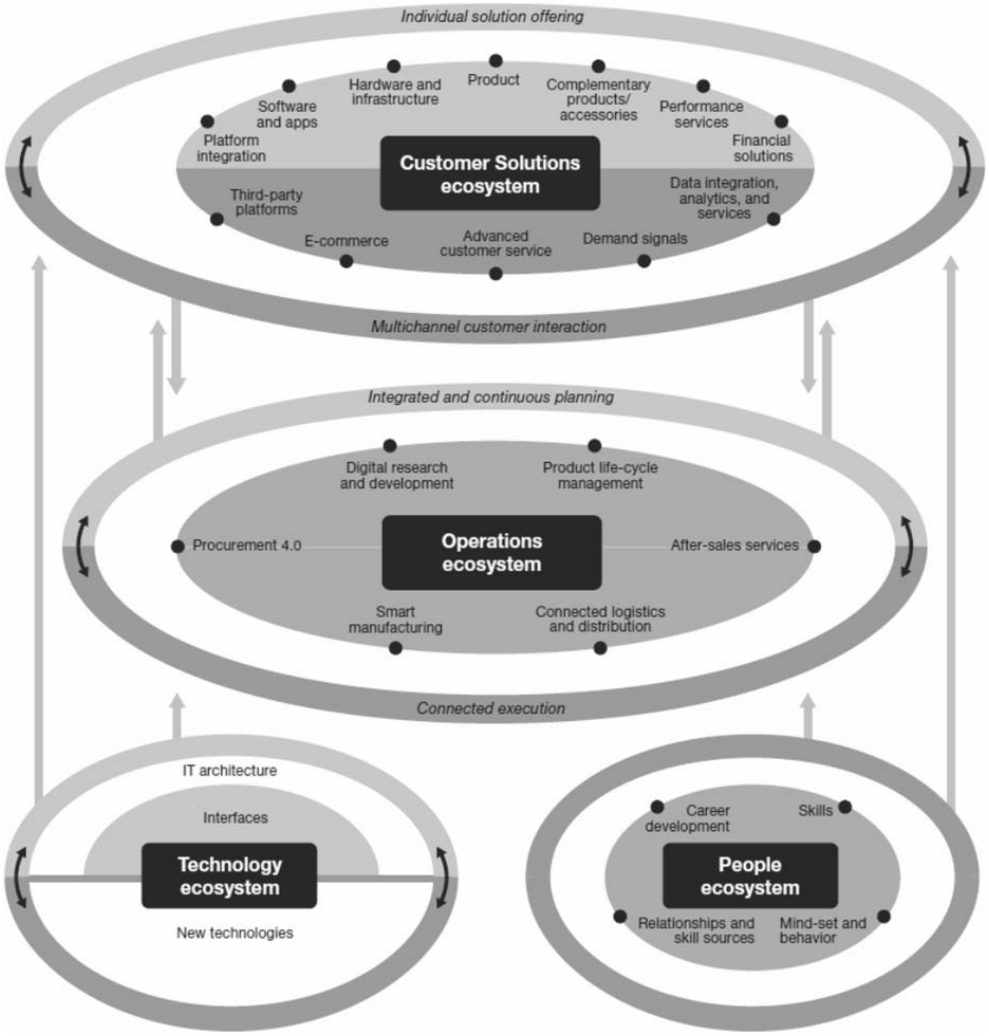
Each of the four critical sub-ecosystems is a set of activities with a wide variety of functions, partners, suppliers, products and services, employees, third-party counselors, factories, outsourcing arrangements, technologies and customers that appear within the company and outside it. These activities are linked through common digital connections and practices, grouped into:

1. The Customer Solutions Ecosystem
2. The Operations Ecosystem
3. Technology Ecosystem
4. The Human Ecosystem (People's Ecosystem).

For any business, these ecosystems have vast opportunities for creating value-added, development and growth in the digital world of the global economy. Schematically the four ecosystems and the connections between them are shown in Figure 1.

In order to develop these ecosystems, the companies will select business partners and create electronic platforms that will unite the four ecosystems into a single body by aligning activities in a coherent overall strategy. None of the ecosystems can be excluded. For example, the customer-oriented eco-system, which is strategically more important and responsive to the market context, can not be developed if the Ecosystem is not endowed with the necessary capabilities, partnerships, technologies, and activities that drive the efficiency of production. The business model, in this case, will not be able to achieve the desired performance.

Therefore, in practice, it is important to correlate the dynamics of the four ecosystems as a whole, effectively integrating available resources and business partners. The industrial ecosystem is at the heart of an innovative digital product chain that optimizes the technologies and skills of human staff involved in the business. In the following subchapters, we propose to examine the role and potential of each ecosystem in the development and economic growth of the entire industrial ecosystem.



Sursa: PwC's Strategy &Global Digital Operations Study 2018.

Figure 1. Industrial Ecosystem Concept.

3.1. *Customer Solutions Ecosystem*

This ecosystem is considered to be the basic component of the industrial system, the business model that puts the customer's (consumer's) needs into account, satisfying it with the best offer of distinctive products and services. The basic function of this ecosystem is to customize products, improve logistics, develop innovative tools and applications to respond appropriately to customer requirements by integrating individual solutions into the overall product and service offer.

This level (subsystem) also incorporates external entities that the company integrates into its solution in order to create added value and solve certain customer problems. Company communication with its customers is completed through multiple channels either directly or through third parties. Within this ecosystem, it is important to understand the needs and preferences of customers by capturing and integrating all relevant signals from their part in a network of internal and external partnerships to gather the information needed to develop new customized products and services.

In our view, the understanding of how the customer-solution ecosystem works, the unique approach and the adoption of product combinations offered with complementary services, highlighting the customer, are the engine of economic growth under the conditions of the technological revolution.

To meet customer needs, the company will use both a network of partners, such as suppliers, industry experts, other companies, and IT knowledge and products, which can be combinations of hardware, software, applications, or interactive platforms. Interaction with customers can be achieved either directly through sales and marketing or through electronic platforms and e-commerce applications. The use of electronic platforms in customer dialogue allows the accumulation of product quality, customer satisfaction degree, objections, and recommendations.

A more detailed analysis of the client-side ecosystem allows us to highlight two priority directions: individual solution offering and multichannel customer interaction. The first direction of development involves the use of information from actors directly involved in transactions (customers and consumers, suppliers, industry experts, industry specialists, etc.) as well as software tools, hardware, digital platforms to provide customized solutions. The second direction of development involves interaction with customers through multiple link channels (e-commerce, databases, digital platforms connecting suppliers with customers, advanced client services, etc.) (See Figure 2).

Source: PwC's Strategy &Global Digital Operations Study 2018.

Figure 2. Customer Solutions Ecosystem Model.

Research in the field of implementing IT solutions in customer service [Kagermann, 2013] found that 50% of the companies that registered the increase in turnover (volume of sales) made considerable investments in the development of innovation platforms and operational support of the business , the sale of products through pay-per-use subscription programs and omnichannel (simply defined as a qualitative and integrated strategy by which the client benefits from the same information and functionality throughout the purchase flow.) Open platforms allow partners and other members of the ecosystem to gather the necessary information from a large number of companies and people at low cost. In this way, companies can generate individual and unique solutions.

A well-defined and mature customer ecosystem creates plus-value for all stakeholders. Surveys have shown that 68% of high-digitization companies have adopted improved customer programs by offering personalized products and services, while 63% have taken advantage of more complex value chains that provide customer products. These companies have created open partnerships with other companies to improve the quality of the products provided. For example, Google and Abbvie pharmaceutical company have partnered to research diseases that affect older people; the partnership agreement between Deere & Company that produces carbon fiber with King Agro technology – to build lightweight and high-quality sprayers for Deere machines; the General Motors alliance with Lyft – for the construction of a self-managed car, the DuPont joint venture with the Hebei Nonghaha Chinese equipment company jointly develops a device that allows accurate planting of corn seeds, etc.

All of these examples share the search for solutions to address certain deficiencies in their area of qualification and the acquisition of missing capacities to provide better products and distinctive services within the ecosystem. These examples also show that it is essential for a company to identify its position in an ecosystem.

Thus, some companies place customer-centric solutions at the heart of the ecosystem, where all participants communicate directly with the company, more than with eachother. Apple is part of this category with a huge suite of application developers who create products and components directly for iPhones and iPads, as well as Deere, the high-precision farm equipment manufacturer, integrates technologies and models from third-party companies to help farmers to accurately measure the use and performance of water resources, seeds, pesticides and other agricultural elements. Some companies place their entity at the base of the ecosystem, with a wider openness to external partners. For example, Ford operates at the end of a traditional supply chain; parts manufacturers have their own components and develop solutions for Ford customers.

Among the main advantages generated by the efficient management of the customer-oriented ecosystem can be highlighted:

1. Obtaining higher revenues in improving the satisfaction of customer needs by offering customized solutions;

2. Increasing production potential through optimal use of internal capabilities and extended network of external partners;

3. Greater agility in managing a flexible network of partners;

4. Higher efficiency and reduced costs.

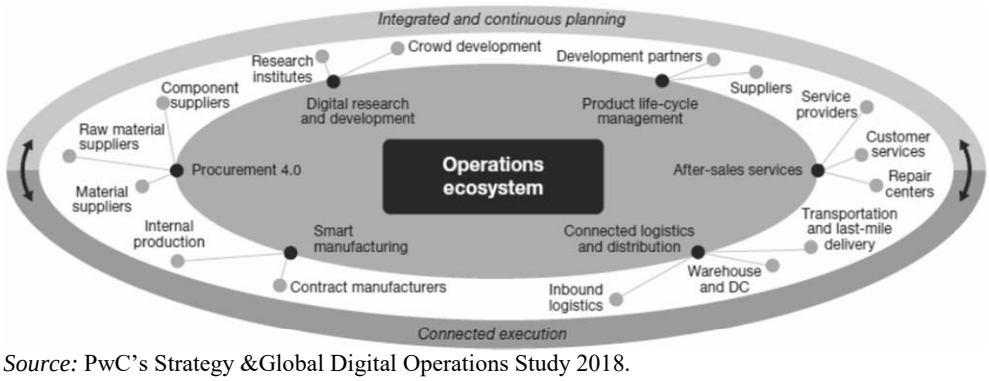
According to the study by PwC & Global [Geissbauer et al., 2018], at the regional level, Asian companies are making the greatest effort to develop this ecosystem (42%), US companies are a little behind 30%, and only 17% of the EMEA (Europe, the Middle East and Africa) were interested in this activity.

3.2. *Operations Ecosystem*

This cluster comprises the activities and physical flows that support the means for the customer-solution ecosystem, also called the value chain efficiency stratum. This layer includes product development, scheduling, supply, production, storage, logistics and customer service. This ecosystem may include any external partners participating in a company's operations, including suppliers, logistics partners, and academia.

The operational ecosystem is the ecosystem layer that serves as the backbone of the company's digital system: the supply chain, product development, production and distribution. Activities within the operational ecosystem can be managed by external entities such as suppliers, contract manufacturers, distributors, logistics providers and inventory managers.

The concept and basic components of the operational ecosystem are shown in Figure 3.



Source: PwC's Strategy &Global Digital Operations Study 2018.

Figure 3. Operations Ecosystem Model.

The operational ecosystem unites the functions and partners on a horizontal basis in R & D, the supply chain and services. A very good functioning of the

ecosystem is particularly valuable for the planning and execution process, as this ecosystem aligns the realization of the value chain (including production and supply) to real-time customer requests. For the manufacturing industry, this ecosystem links vertically and automates production processes and connects outlets to the supply chain.

An important factor is the relationship between the operational ecosystem and the customer-solution ecosystem. In mature digital business models, the operational ecosystem derives directly from customer needs.

The significance of this correlation is obvious, for example, to deliver customized product deliveries to customers, the company must have a supply chain, execution capabilities, and a flexible production process. Because the characteristics of products or services change over time, the composition of the ecosystem can be continually modified and improved. Suppliers, warehouses or factories may be needed in new regions; more flexibility to deliver just-in-time accelerated programs; and the innovative logistics partners needed to overcome competitors by offering customers greater variety and comfort. Unlike the classic organization of the operational process (separate departments for research and development, production, control and management, sales, etc.), the ecosystem is managed by two layers: the integrated and continuous planning layer, and team-based implementation executives, the team being composed of internal and external members who are attracted to specific tasks and projects and can be dissolved when the projects are completed. The teams in question have to ensure the ecosystem functionality that has to deliver the desired solutions in the upper ecosystem.

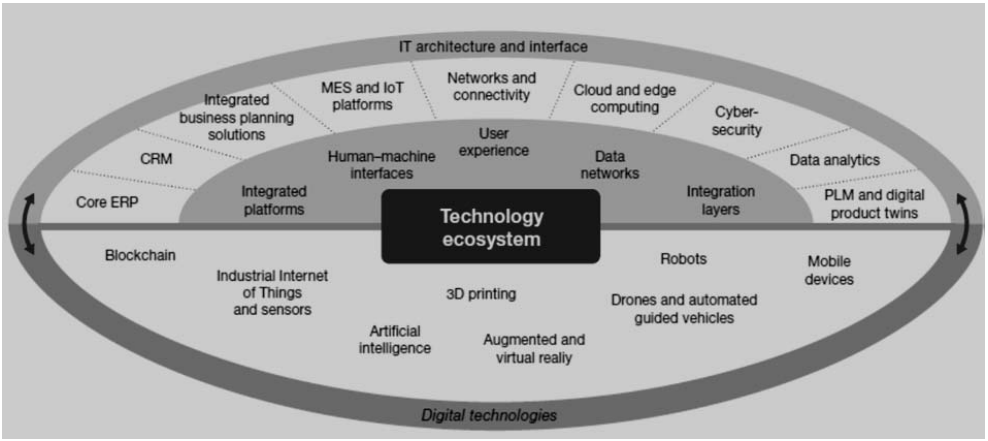
For example, these companies can exchange information about the product qualities in several stages of the value chain almost instantly. This allows them to quickly assess the impact of demand change on all stages of the value chain and address any constraints that would hinder adjustment of the production process and sales program.

3.3. *Technology Ecosystem*

This layer is the backbone that ensures the implementation of new technologies throughout the company. The technology ecosystem coordinates improvements and innovations in customer-solutions, operational and human-ecosystems,including interfaces and the IT architecture of the company. It includes Industry 4.0's pivotal technologies as 3D printing, artificial intelligence, Internet of Things (IIoT), sensors, virtual reality, and robots. The model of the technological ecosystem is shown in Figure 4.

The basic task of this ecosystem is to ensure business digitization by automating the processes of planning, producing and serving customers. Software is often built in the cloud and contains applications with high security for data analysis and storage. The ecosystem interfaces link the IT architecture with the integrated platform user, human machine interfaces, data networks, and other industrial integration

layers. All of this is developed in a coordinated way to provide superior quality products, experience, reliability and efficiency.



Source: PwC's Strategy &Global Digital Operations Study 2018.

Figure 4. Tehnology Ecosystem Model.

Leading companies in the application of IT innovations promote the intelligent expansion of technologies across the entire industrial ecosystem implementation and rapid development, forming partnerships with external platform, hardware and software vendors. Finally, these partnerships ensure the valorisation of the IT innovation tools in the whole range of ecosystems of the company, internally and externally.

Implementation of information technologies in economic activity should not be done solely for the sake of technology, or to keep pace with international market trends, managers need to understand the competitive advantage of IT – speed, flexibility, personalization and efficiency. Industry Technologies 4.0. widely applied in manufacturing are:

1. Integrated planning of the supply end-to-end chain;
2. Predictive maintenance of assets and products;
3. Production execution systems;
4. Industrial Internet of Things;
5. Digital twins, virtual versions of physical assets, products, or digital factories;
6. Advanced Robotics, etc.

Many of the world's manufacturers are active in implementing and piloting augmented reality (AR) and virtual reality technologies (VR). They provide computer-generated simulation of complete three-dimensional images that allow the user or client to interact realistically with the virtual environment. These technologies are valuable for maintaining and developing production capacities, customer service and quality assurance. They are also useful for self-learning and training as well as for the rapid adaptation of the workforce to changes in the operational process, and for the rapid integration of employees into the production process.

Advantages generated by the technological ecosystem enhance company performance. These advantages create a virtual circle – any efficiently used digital technology is the starting point for additional, improved technology that will generate new economic benefits. Of course, in order to benefit from the technological ecosystem, companies need to have an advanced information culture and a set of skills for optimal use of technologies.

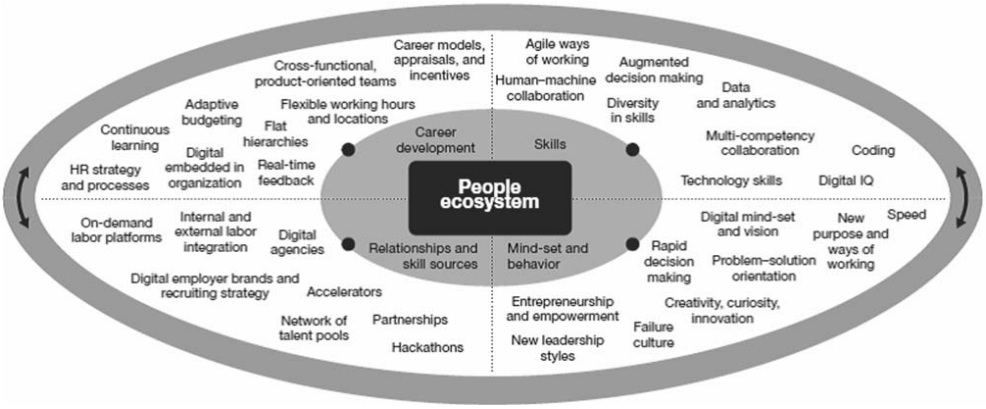
In order to transform general applications into information property that meets operational needs and serve the company, considerable investment is needed. Intelligent digitization and automation of production processes allows a high level of personalization of the finite product and speeding up the satisfaction of consumer preferences, and the latter are the hallmarks of Industry 4.0.

3.4. *People Ecosystem*

Currently many companies lack the vision, strategy and culture needed to support their digital transformation. Another substratum of the industrial ecosystem, which represents the field of competence and organizational culture, is the human personal ecosystem that encompasses the skills, competences and knowledge necessary for the adoption and use of digital products.

The elements of this ecosystem are characterized by the company's strategic directions (solutions) and performance (operations). By assessing these factors, the types of digital activities and skills needed to support human staff efforts to improve the performance of IT deployment activities can be determined.

The human personal ecosystem (employees) embodies the internal workforce but also self-employed workers, contract workers, digital agencies or scientific research institutions and universities. The human personal ecosystem model is shown in Figure 5.



Source: PwC's Strategy &Global Digital Operations Study 2018.

Figure 5. People Ecosystem Model.

Ensuring the skills and organizational culture needed to implement IT can be achieved by providing and developing the main components of the human personal ecosystem:

1. Skills: Workers exhibit different abilities in their work, interacting with machines and machines, taking decisions derived from the technology applied in the production process. For the development of the ecosystem, the company has to invest in increasing the digital IQ of the labor force.

2. Mind-set and behavior: includes a set of rules of conduct, leadership styles, openness to new technologies, an open culture of communication, creativity and innovation, a non-hierarchical mentality, "best idea counts" decision-making and problem-solving.

3. Relationships and sources of qualification: the organization is made up of functional teams with internal and external integration; who continuously trains themselves using platforms, networks, or databases. In this respect, performing companies create clusters with training and research centers, develop a recruitment and recruitment strategy for thestaff that characterizes its digital maturity, develop talent development and innovation programs.

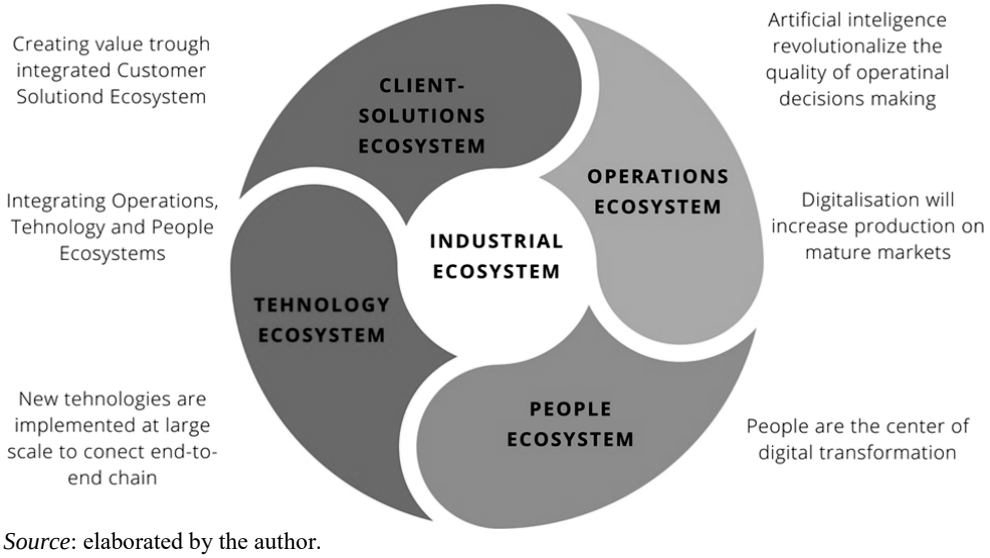
4. Career development: Company management appreciates, stimulates and rewards innovative ideas, and is interested in the ongoing digital training of its employees.

Smart digitization and automation will contribute to a 14% increase in global GDP by 2030. Mature markets will benefit more from digitization by lowering operating costs, allowing companies to rely less on workforce and to increase the volume of production on domestic markets. In turn, demand for skilled labor will increase, as are wages and the need for skilled work – especially for digital experts, data analysts, advanced technology specialists, engineering and mathematics (STEM). Demand for innovation, access to talent, and industry-specific 4.0 programs will be crucial.

4. Conclusions and recommendations

The understanding of an industrial ecosystem and the ecosystem vision of all component elements is the starting point for growth and economic growth under the conditions of Industry 4.0. The development of an integrated ecosystem system and a well-defined internal and external strategic partnership model, efficient governance of ecosystems that prioritize activities, enables rapid decision-making and makes best use of them. Digital investments are key to successfully deploying, expanding and improving customer solutions, operations, technology and human skills.

The main recommendations for companies that want to develop their own industrial ecosystem to achieve economic growth under Industry 4.0 are shown in Figure 6.



Source: elaborated by the author.

Figure 6. Six Key Findings for an Efficient Industrial Ecosystem.

In conclusion, we found that obtaining a competitive advantage is possible through the orchestration and integration of the four layers of subsystems: Client Solutions, Operations, Technologies and People. Through Customer Solutions Ecosystems, Customer Solutions Ecosystem creates new value by continuously improving product offerings and digital services, such as access to customers, directly or through third parties. Worldwide successful manufacturers excel by creating customer databases and matching customer requirements with the solutions they offer, improving traditional products with services, software, data analysis, and added value on partner network accounts. To do this, manufacturers can use open platforms to remove internal and external borders in business.

The "customer solutions" ecosystem serves customers with complete digital technology, products and services with a network partner. Client solutions are supported by an "Operational Ecosystem" – a correct set of technologies, personal and cultural to lead them. Digital leaders are adjusting their businesses, identifying strengths to define client solutions, and at the same time allowing customers to set new targets for the operational ecosystem and the human (human) ecosystem. This alignment creates an industrial ecosystem that will have a strategic advantage. Digitization will help increase productivity in mature markets and get closer to customers by manufacturing customized products. Globally, digitization will increase productivity and improve living standards.

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