The Fourth Industrial Revolution: history, design, and the impact on the private sector

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Abstract: *The Fourth Industrial Revolution (or the 4IR) emerged quite recently as a concept that describes the unprecedented transition of society towards a life governed by artificial intelligence, hyper-connectivity, and cyber-physical systems. To fully understand it, a short review of the previous revolutionary moments will be illustrated, focusing on their footprint on humanity, as well as on the business sector. After that, a definition framework will be constructed, that shows the structural design behind 4IR, from the fundamental characteristics to the technologies that it deploys. Lastly, as expected, when systemic dynamics are implied, the private sector will be the most reactive actor, playing the role of the transition enabler and the starting point of its dissemination. Therefore, the 4IR impact will be the most evident through the development of new, state-of-the-art business models, that will ultimately ensure the very fast process of adapting to contemporary reality. In the current paper, three examples will be described: the digital platform, the smart factory, and the industrial internet-of-things, which are based on five decisive characteristics: connectivity, access, innovation, autonomy, and cost efficiency.*

1.1 The Four Industrial Revolutions

When discussing the Fourth Industrial Revolution, the first thing we need to capture is a chronological understanding of the concept. Therefore, there will be four major moments in time, defined as revolutions, that inflicted major changes on society as a whole. Those moments generated a complete and abrupt redesign of the world, being facilitated by the most important advances in science, industry, and technology. Even though the fourth revolution might face some critique and controversy, the related literature seems to be in agreement regarding the first three periods and their representation as turning points in history. As a result, in this section, we will shortly describe them and their consequential impact on humankind.

Starting with the first industrial revolution, this period marked the transition from an agricultural society to the industrial one, fueled by the discovery of coal, steam, and water mechanics. As (Deane, 1979) mentions, the moment corresponds to a way of escape from poverty and the start of the affluent societies of today. The core of this period, happening in the 18th century, will be the invention of the steam engine, patented by James Watt in 1769. Along with this new mechanism, a brand-new notion will be introduced: that of production and industry. The effects were clear: global economic growth and a constant increase in both production and consumption for the common people (Mohajan, 2019). More than this, the transition from agricultural and animal labor to the use of machinery meant creating new jobs, involving more diverse categories of people, and developing skills that ultimately lead to an increased quality of life and overall reduced mortality.

Following that moment, a hundred years later, at the end of the 19th century, electricity will upscale every productive process, introducing the notion of mass production. Water and coal will be replaced by gas and oil, and the main core of production, the steam engine, will be replaced by the internal combustion engine, reaching totally new capabilities. The period can be described as a steady accumulation of useful knowledge (Mokyr & Strotz, 1998) with more and more technologies being built that extended the range of products and services. Consequently, the entire organization of production has changed, starting from the actual machinery, such as the assembly line, to the main economic principles besides industry success. Concepts such as economies of scale, measured productivity, or standardization became prevalent, as well as different forms of competition or marketing strategies. More than that, the core of nowadays economy, namely the giant corporations, were developed for the first time, rapidly gaining power, influence, and market shares. Besides the industrial perspective, lifestyle has also changed significantly. The great advancements in transport and communication, through the extension of the railroad networks or the invention of telephones, generated new opportunities and unprecedented freedom of movement. However, not everything related to this era is positive, along with the accelerated economy, a great deal of poverty spread around the population since not everyone has been so quick to adapt to the new dynamic. The middle class and white-collar jobs become the core segment of society, while the poor working conditions exposed the employees to great dangers. All this will be interrupted by the two world conflagrations that shifted the entire society to a massive, war-focused industry.

Starting in 1950, the Third Revolution will become the new framework for defining modern life, with another source of energy taking the spotlight: nuclear. Once again, the historic context will play a major role, the second half of the 20th century being described as a complex and constant state of alert that pushed multiple states towards embracing and integrating the new revolution. However, this period will be slightly different from the ones before, since the main core of the transition is represented by information, the most important intangible asset anyone can possess. Therefore, any invention that was generated during this time revolved around the concept of information: from the first computers to the invention of the internet or the further devices that enabled its processing, transition, and understanding. Moreover, what is important to grasp about this moment is the fact that even though steam, coal, and electricity are still largely used, they are becoming more of a currency, rather than a core-productive factor that can produce a significant shift in the economy as we know it today. In other words, material resources are still a key factor, but they are not producing any new value, innovation, or progress. In contrast, the high potential and combinative power of different information technologies are actively changing entire industries and lifestyles.

However, when it comes to evaluating the general impact of those technologies, there are multiple lenses to see through. The first one would be marked by the changes in the dominant energy source and the switch to nuclear power and then to the renewable and green energy narrative. The second one will refer to the changes in the dominant technologies, towards information and data. Finally, the main poles of international power have also changed, as (Janicke & Jacob, 2013) will mention, China and India starting to play a huge role, in their research framework of studying the technological development of western societies and then building and adapting the principles to their industries. However, besides certain actors leading the acceleration race, globalization will remain the most evident effect of this period, with the trans-territorial connections becoming omnipresent and even imperceptible.

Reaching current times, the Fourth Industrial Revolution (4IR) will be the moment in which a fusion of technologies will blur the lines between the digital and physical worlds. This revolution, which started a decade ago, seems to be the most disruptive and radical, since it changes every aspect of life, replacing it in total with cyber systems that are complex and extremely smart. Starting from the breakthroughs in biology, to the ones in the energy sector, artificial intelligence, quantum computing, or nanotechnology, all these will give the right to call the current context a true revolution. More than that, the phenomenon is happening with an extremely fast rhythm, having a global contagious effect and a very clear goal: connecting both machines and people, in collaborative, fully integrated systems, with high autonomy, that will introduce an era of omni-use, connectivity, and minimized human intervention.

1.2 Related literature

One of the pioneers of the Fourth Industrial Revolution as a concept is Klaus Schwab, the World Economic founder and executive chairman. He will extensively describe his understanding of the new era as a period, unlike anything humankind has ever experienced before, inflicting dramatic change all around us and even challenging ideas about what it means to be human

(Schwab, 2017). Although it might sound grave and consequential, the main principle behind it it's simple: to develop a connected world, that manages to find an equilibrium between human intelligence and human necessity. In other words, as (Schwab, 2018) will also reassure, this world still needs to be developed by someone, so the technological landscape remains one made by people for people, the only ones that can give it structure and purpose. The difference however is laying in the needed intervention: the 4IR will propose an industry in which people are no longer responsible for mundane, repetitive tasks that can be easily replaced by machines, similar to the second and third industrial revolutions. What is different this time, is the fact that they will also lose a certain amount of control and power of decision, since the new technologies are meant to provide a high level of autonomy, self-learning, optimization, and diagnosis functionalities. So, the cycle doesn't exclude human labor, but it profoundly reconfigures it, starting from how people create, exchange, and distribute value (Philbeck & Davis, 2018). This process will have indeed a strong disruptive potential to fragment society, but it will also provide an opportunity to build a brand-new social foundation, around values like the common good, human dignity, and intergeneration stewardship (Schwab, 2017).

Further on, in the related literature, there is a confrontation between whether the Fourth Industrial Revolution is a distinct moment or a continuation of the third. The main advocators of the first scenario will base their theory on three main elements, to demonstrate that nowadays transformations are distinct and recognizable: velocity, scope, and impact (Xu, David & Kim, 2018). First, the velocity will refer to the evolution rhythm, and as mentioned before, this revolution seems to be moving at an exponential speed. The scope, or the breadth and depth, will focus on how a phenomenon changes the way we perceive, conduct, and evaluate all fields of activity: whether it is economy, industry, business, or politics. In correlation with the scope, the system impact or the paradigm shift will involve the transformation of entire systems, without time or space limitations, towards new frameworks and workflows. So, using these three elements, we can describe and validate the new revolution, since they are in perfect synchronization with the effects the 4IR already generates on a global scale.

On the other side, the scholars that consider this Industry 4.0 as being a prolongation of the third revolution will argue that the concept is a marketing strategy, that doesn't inflict systemic change, but only develops and extends the use of the internet and data that started 30 years ago. To further support it, Jeremy Rifkin will present the third revolution industry as a process that humanity is in front of, with the core elements being the transition towards a sustainable post-carbon era, the aversion of climate change, and the emergence of the collaborative age (Rifkin, 2011). So, for that to correlate to the chronology of moments, Rifkin's vision implies that the second and the third revolutions described before were merged and not distinct.

1.3 Main components and impact

Circling back to what the Fourth Revolution actually implies, the main element of this revolution would be the CPS or the cyber-physical systems, which have integrated different computational and physical capabilities useful in the production flows. This new generation of systems aims to control physical processes by constantly receiving information, measuring, and evaluating different parameters, and eventually constructing their own feedback loops. When it comes to the opportunities they provide, enhanced efficiency and support in the decision-making process will be on top of the list, but their final goal will be to revolutionize the way enterprises conduct their business from a holistic viewpoint (Colombo et al., 2017). Therefore, many innovations will be based on CPS, such as airplanes, autonomous vehicles, or even brain prostheses (Baheti & Gill, 2011). That is explained by the fact that CPS as a concept can integrate a vast deal of new technologies, so a summary of those is necessary to understand what it means in terms of practical implementation. To do that, we have identified a classification approach based on the three fields of activities in which they are most likely to be deployed: production and services, lifestyle, and data. However, we need to mention that all these technologies remain in a constant state of confluence and convergence and the list is being updated as we speak.

Table 1. Main technologies of the 4IR.

Production and services	Lifestyle	Data
industrial internet of things, digital twin, signal processing, nanotechnology, autonomous robots, additive production, 3-D printing, business intelligence, digital trade, sensors, simulation	Internet of things, augmented reality, genome editing, synthetic biology, metaverse, autonomous mobility, drones, precision medicine	machine learning, big data, system integration, cybersecurity, cloud computing, blockchain and DLT (distributed ledger technology), data ecosystem

Source: self-processing, based on the review of the related literature.

Further on, in the current paper, the focus will be on how the above technologies affect the business sector and the general impact of the Fourth Industrial Revolution on an organizational level. A first method of measuring this impact will be illustrated by Schwab, clustering the effects into four distinctive categories: customer expectations, product enhancement, collaborative innovation, and organization forms[1] . First, the new technologies will connect the customers to the entire production flow (Prisecaru, 2016) and even put them in the center of all activities, becoming the epicenter of the economy. To satisfy their needs and meet the demand, products will be enhanced, and all the information and digital assets will increase their value, through innovative processes. To add on that, the organizations will have to restructure their workflows and find new forms of collaboration, in order to keep up with the competition, fight devaluation and depreciation and keep their relevance in the market. At the same time, a very important aspect is that of sustainability and what it means to be a sustainable enterprise in the 21st century and to find the right balance between stability and change (Ionescu & Cornescu, 2010). Finally, another important aspect, already mentioned in the previous section, will be the focus on increased productivity which could ultimately be a synonym for the displacement of workers with machines. This could generate great inequality in the labor market and a race between humanity and technology (Brynjolfsson & McAfee, 2012). However, the social effects remain to be seen since for

1 https://www.weforum.org/agenda/2016/01/the-fourth-industrial-revolution-what-it-means-and-how-to-respond/. Last accessed, 29/10/2022. https://www.weforum.org/agenda/2016/01/the-fourth-industrial-revolution-what-it-means-and-how-to-respond/. Last accessed, 29/10/2022.

the new economic framework to work, a solid equilibrium between resources, costs, and results needs to be found.

Overall, the new 4IR platforms will improve the quality, price, and distribution models, helping companies have a better response to diverse challenges, such as volatility, product life-cycles, and global supply chain (Morrar, Arman & Mousa, 2017). Therefore, as (Marinescu & Toma, 2015) mentions, changeability constitutes a key competitiveness factor for any company, so as soon as the private sector understands and includes this principle in its strategy, progress will also appear. But what remains to be addressed, is how exactly will the new technologies impact businesses and how can they create value. By studying both the related literature (Lee et al., 2018), (Xu, David & Kim, 2018), (Tohanean & Toma, 2018), (Bloem et al., 2014) and multiple private case studies (pwc[2] , Deloitte[3] , Forbes[4]) we have summarized five characteristics of the new technological landscape that have the potential to inflict radical change. They will be shortly described below and then demonstrated throughout the illustration of the newly designed business models.

Connectivity – the ability to integrate multiple machines, platforms, humans, and devices to increase the communication capacity within a network. This effect will be the first gateway to the transition towards the 4IR, improving all business flows and encompassing new ways of maintaining contact between agents.

Access – the ability to provide entrance to any informational resource, especially in the digital and virtual environment. As mentioned before, information will be the most valuable asset in the new business world and immediate access to data that can be transformed into knowledge will make the difference between a slow-adapting business organization and one that is capable of agility.

Innovation – the ability to create, evolve, extend, or accelerate new value. Innovation will be imperative for all business activities, from distribution to production, marketing, or sales. This will boost the response capacity, provide a framework for assessing and avoiding risks and help build long-term strategic growth. More than that, as (Herman & Nistor, 2020) will point out, innovation will help companies cope with declining product cycles and faster new technologies.

Automation and Autonomy – the ability of the new technologies to perform tasks on their own, based on previous supervised or unsupervised learning processes. The newly deployed machines will be able to diagnose issues, identify the optimal solution, or monitor remotely without any human intervention. The effort and the time resources will be optimized, by providing capabilities that ultimately change the rhythm, volume, materials, or flows of production.

Cost Efficiency – the ability to alter the costs, by building economies of scale and an increased return on investment. This characteristic will be in a symbiotic relationship with the automation

2 https://www.pwc.com/us/en/library/4ir-ready/fourth-industrial-revolution-economic-downturn.html Last accessed: 29/10/2022.

3 https://www2.deloitte.com/content/dam/Deloitte/de/Documents/human-. capital/Deloitte_Review_26_Fourth_Industrial_Revolution.pdf. Last accessed: 29/10/2022.

4 https://www.forbes.com/sites/forbestechcouncil/2020/08/03/how-businesses-can-thrive-in-the-fourth-industrial-revolution/. Last accessed: 29/10/2022

part since robots and the adjusted machinery have a high potential to reduce operating costs, offer predictive maintenance, and avoid cost injuries related to human activity.

2 Business models

Regarding the business models (BM) analysis, before describing some of the newest and most efficient frameworks of the Fourth Industrial Revolution, it's important to first define them. Therefore, a business model will be a configuration that describes the way a business enterprise is organized and the way it delivers value to the customers, while also making profits (Teece, 2010). Other authors have described the concept as the design of the transaction content, structure, and governance (Zott, Amit & Massa, 2011), with the specific role of creating a heuristic logic that will connect the technical potential to the actual production of economic value (Chesbrough & Rosenbloom, 2002).

When it comes to the 4IR, the definitions are much more limited, since the new business models present a high level of adaptability, an integrated dynamism, and a high dependency on technology, so they cannot be so easily defined. What can help in this manner is illustrating certain ways of classifying the 4IR BM, based on different criteria. Consequently, one interesting framework would be the one developed by (Bagnoli, Dal Mas & Massaro, 2019). The authors will start from the main goal of a business model: to construct new ways of developing relationships with the customers and to deal with knowledge management systems. Based on that, they will identify four main categories of BM: mass-customization, which will focus on understanding the client's needs and providing a more on-demand approach, servitization, which will propose a way of transforming the products into services, data-driven, which will use the embedded value of information in the production process, and platform, that will aim to facilitate the entire exchange of resource throughout the ecosystem.

Another way to study the business model structure would be by circling back to the theoretical methodologies. One of the most used ones would be the Business Model Canvas, which has been developed by (Osterwalder & Pigneur, 2002) and continues to be extremely popular in the related literature (van Tonder et al., 2021). According to this framework, a business model can be studied using four main pillars: product innovation, customer relationship, infrastructure management, and financials. We can already see that the elements will be very similar to the five characteristics exposed in the previous section. Therefore, innovation will be found explicitly in both, the financials will integrate the cost-efficiency capability, and the infrastructure will embody the connectivity, access, and autonomy of the network. Finally, customer relations will add a new dimension to the business model, since the most adapted companies will be the ones that know how to engage their customers and create long-term transactional, functional, or strategic relations.

Having now a clear framework of analysis, we will further focus on three distinct models, that can be considered representative of the Fourth Industrial Revolution: the digital platform, the smart factory, and the industrial internet of things. They will present the five characteristics described before, as well as demonstrate the combinative power of multiple technologies.

2.1 The digital platform business model

The digital platform business model will be a structure that creates value by facilitating exchanges between different entities, such as CPSs, humans, and devices, into a single informational and intellectual space (Geliskhanov, 2018). In other words, the new model will not produce anything directly and won't have linear and traditional supply chains or distribution flows, but it will incorporate services and applications that respond to a certain digital need. The concept can be compared to digital ventures, which will be a type of enterprise that trades and operates exclusively online (Stancu et al., 2017). The model has gained exponential popularity, while also absorbing a great share of business value, whether we refer to the number of customers, revenue growth, or market share. (Cohen, 2017) will describe it as the core organization form of the emerging informational economy, a description proved correct by the current status quo: 7 out of the top 10 most valuable international companies already operate this model and are forecast to handle 30% of the global economic activity by 2030[5] .

The principle behind this model is based on identifying customers' needs and building an ecosystem in which multi-functionalities respond to those specific needs. This ecosystem will be a perfect combination of software services, physical products, and platform facilities and will handle entire business processes, integrating the supply and the demand of economic activity. (Geliskhanov, 2018) will describe them as being both a transaction institute and an organizational institution. That means that they will offer multiple transitionary facilities, from the movement of information, goods, and services, to providing rapid intermediation between actors, increasing the awareness of certain products, or removing barriers to certain industries. At the same time, the model will also organize the users' interaction, by providing the architecture, pricing systems, and necessary configuration for the actual transactions to happen, demonstrating its potential as an organizational structure.

Further on, being one of the most used models nowadays, its complexity has increased significantly, while also facing a decomposition phase. Therefore, similar to the definition process of the business model, it would be easier to understand it when identifying distinct criteria of classification. As an example, we can look at agents' interaction and group the digital platform into three categories, as follows: business-to-business (B2B), business-to-consumer (B2C), and consumer-to-consumer (C2C). The first one would encompass all the sales channels and tools necessary in the interactions of a company, successful examples being Microsoft, Oracle SuiteCommerce, or even Google. The second one would be the most frequent, since it will be designed for the direct use of individual consumers and their according needs, whether it is entertainment, shopping, or transport (Netflix, Walmart). However, the third one is becoming more and more popular after the pandemic context, since they offer consumers a direct trade mechanism, where they have full control over their actions, decisions, and budgets (eBay, Craigslist).

Although it can already be grasped from the previous classification method, another way to analyze digital platforms is by looking at the main scope, whether it is sales, meeting a specific need, or building an information space. For example, the sales-driven models would be

5 https://www.weforum.org/agenda/2019/01/is-your-business-model-fit-for-the-fourth-industrial-revolution/. Last accessed 30/10/2022.

represented by the e-commerce platforms (Amazon, Alibaba, eMAG), which will allow multiple vendors the opportunity to sell and promote their business. In the second category, we have the applications that satisfy a certain need, by providing new or redesigned services, while also challenging entire industries (Uber, UberEats, Airbnb). Lastly, the third category, namely the social media platforms will be the most popular since they can integrate vast interaction capabilities (Facebook, Twitter, LinkedIn) and construct an informational space for alternative activities: education, entertainment, journalism (Quora, YouTube, Yahoo). Moreover, depending on their structure and profit mechanism, other configurations will be profiled, such as the multi-side commission fee, listing fee, pipeline model, or submission fee.

However, regardless of the monetization schema of the new business models, we reiterate the most important question, namely how they create, capture, and deliver value in the ecosystem, since they generate massive costs of developing and maintenance of the general architecture (Hein et al., 2020). A possible response would come from the exponential popularity they gained in the last 5 years, most incumbent companies choosing now to participate in a platform that is operated by a third party, rather than building its own[6] . So, there will be multiple concentrations of brands into platforms that ultimately don't split profits but provide economies of scale and almost zero marginal costs. Another argument is coming from the indirect network effects they generate, being the most evident in the marketplaces where multiple suppliers will mean multiple customers and multiple customers will ultimately mean multiple suppliers. As a result, the value cycle is completed, has integrated its feedback loops, and can be improved by finding patterns through the advanced use of raw data. This last concept would be a key function of any digital platform since its main objectives are to build the correct audience and optimize the matching between customers and information, while also making sure they implement correct standards and rules for users' interactions.

In conclusion, the digital platform model proves to have all five characteristics previously described, connecting different sides of the purchasing process, offering access to a vast volume of information, products, and services, and proving their innovation through easy-to-use functionalities that answer many users' needs. The companies that already operate this model have a highly automated structure, driven by artificial intelligence and machine learning techniques. Finally, they provide a cost-efficient structure, gaining impressive profits year on year and being some of the most looked-for choices for personal investment.

2.2 Smart factories

The second model relevant to the Fourth Industrial Revolution is the smart factory, a concept that doesn't have a unified definition and is being understood as a flexible and configurable productive structure. (Hozdić, 2015) will propose a conceptual definition in which the main goal of the new entity would be to solve problems arising in a production facility with dynamic and rapidly changing boundary conditions in a world of increasing complexity. In other words, a

6 https://www.mckinsey.de/~/media/McKinsey/Business%20Functions/McKinsey%20Digital/Our%20Insights/The%20right%20digital%20platform%20strategy/The-right-digital-platform-strategy.pdf Last accessed 29/10/2022.

smart factory will be an environment that organizes itself and provides improved manufacturing facilities, by employing highly connected machines. The concept will be frequently found in the related literature as an extension or a key construct of Industry 4.0 (Wang et al., 2016), (Shi et al., 2020), (Osterrieder, Budde & Friedli, 2020), but this will not be equal to a unified framework or roadmap of implementation. As with any new business model from the 4IR, each company will adapt the concept to its own needs, resources, and decision-making style, to ultimately improve the general key-performing indicators.

Referring to its structure, a smart factory can be described from the perspective of three layers or resource allocation plans: physical, network, and data (Chen et al., 2017). The physical layer will consist of all equipment, devices, and real-time hardware that ensures the informational flows. The network layer is the one that reunites all the business activities in a cooperative schema that guarantees the production, transmission, and control, being extremely connected to the data application layer. In other words, the network entity will provide the format and the protocols, while the actual data will turn into a self-learning instrument. It's important to mention that data acquisition and analysis will be extremely relevant in the automation process, ultimately providing the intelligence factor in the production equation. However, all three layers will have an equal contribution to the success of the implementation, existing in an interdependent state.

Watching the developments from the actual industrial reality, Germany seems to be not only the pioneer of smart factories but also of the strategic initiative named Industrie 4.0. As a direct consequence of the several strategies and action plans adopted by the government, we can already see successful examples of smart structures, such as the Tesla Gigafactory, the Adidas Speed Factory, the Bosch Connected Factory or the Siemens Elkronikwerk Plant from Amberg[7]. The German private sector perfectly understood that the changes inflicted by the smart capabilities are not only desirable but mandatory, since the consumers' needs are dynamic and unpredictable, so organizations need to be able to adapt fast and cost-efficient. More than that, although the initial investment might be costly, the general advantages they present in the long term are balancing the expenditure: they help companies integrate sustainability and safety regulations, ensure product quality and excellence in execution, and improve overall customer experience and productivity[8].

To add to the above, if in the previous case, of the digital platform model, the focus was on the digital aspect, by creating and handling intangible assets, for the smart factories the main principle will remain the actual production of physical goods. That means that they will encompass multiple technologies which improve the manufacturing process, from cyber-physical systems to cloud computing, predictive maintenance, 3D printing, smart sensors, or big data analytics. We will describe two of them, namely sensors and big data, to understand how a smart factory structure works and the main changes they inflict on the production lines.

Sensors will be one of the most frequent instruments employed in a smart factory since

7 https://www.rokin.tech/post/intelligent-manufacturing-5-examples-of-smart-factories-across-germany. Last accessed 30/10/2022.

8 https://www.sap.com/insights/what-is-a-smart-factory.html. Last accessed 30/10/2022.

they present the capacity to continuously collect, process, and monitor data from a physical phenomenon, while also codifying it in a digital system. Therefore, they will be extremely important in the production flows, having the power to identify issues or changes in parameters, provide control points or generate new impulses or outputs. Their main functionality will be recording and generating feedback from a network, by transforming inputs into a certain, desired output. As a consequence, a way of classifying sensors would be by the type of input they sense from pressure to temperature, proximity, humidity, force, gas, color, or light (Javaid et al., 2021). Other classification methods would look at the size (nano, micro, or macro) or at the way they convert the stimulus, by using one conversion step (direct) or multiple intermediate (indirect). However, regardless of their size and inputs, they remain one of the most efficient and popular instruments that can track the entire process of production by offering enhanced capabilities, such as process automation, building automation, asset monitoring, or predictive maintenance.

Another important technology worth describing will be Big Data methodologies, which will amplify the vast and complex process of performance analysis. In the last ten years, this subject has captured the attention of many different stakeholders, including governments, scholars, and private companies. Consequently, there will be multiple frameworks that aim to define and explore its potential. One example would be the McKinsey Global Institute, which will describe this field as the next frontier for innovation, competition, and productivity[9]. When asking the same question as before, namely how big data creates value, the institute's arguments are based on five capabilities: transparency, enabling experimentation, tailored segmentation, replacing and supporting the human decision, and development of the next generation of products[10]. Referring strictly to the manufacturing process, the advantages will multiply, from improved demand forecasting, to supply chain planning and control, or operational and sales support. At the same time, this new concept will employ multiple changes of paradigms, such as the switch to flows as opposed to stocks, the reliance on data scientists and not data analysts, or the transition of analytics from the IT departments to the core business, strategic, management and operational functions (Davenport, Barth & Bean, 2012).

However, we cannot discuss big data without illustrating the most known framework of definition, the three V: variety, velocity, and volume. They were first introduced by (Laney, 2001) and then used in multiple publications to describe the differences between big data and traditional data analysis (Sagiroglu & Sinanc, 2013). Therefore, the variety will refer to all the data sources and types such as structured, semi-structured, or unstructured, volume can be understood as the amount or size of data, as well as the adjacent technology that has been constructed to be able to manage and process such quantities, and velocity will refer to the processing speed. Some sources go even further and add two more characteristics, the value and the veracity[11],

9 https://www.mckinsey.com/~/media/mckinsey/business%20functions/mckinsey%20digital/our%20insights/big%20data%20the%20next%20frontier%20for%20innovation/mgi_big_data_exec_summary.pdf Last accessed 30/10/2022.

10 https://www.mckinsey.com/capabilities/mckinsey-digital/our-insights/big-data-the-next-frontier-for-innovation. Last accessed 30/10.2022.

11 https://www.teradata.com/Glossary/What-are-the-5-V-s-of-Big-Data. Last accessed 30/10/2022.

or the quantifiable business benefits and the accuracy of data. But once again, regardless of the definition framework, big data, through its prescriptive, descriptive, and predictive power will manage to enhance any productive or commercial process, being applicable in all fields of activity and inflicting radical and almost immediate change. That is why, big data remains one of the fundamental technologies employed in a smart factory, without which the innovation dimension will not be feasible.

In conclusion, the smart factory, through the employment of sensors and big data, but not limited to it, is proving to be a winning model in the current business environment. It constructs a highly connected, automated, and accessible ecosystem, that is capable of innovative insights, while also providing multiple cost savings. In a world of increasing complexity, this solution checks all the key features of the 4IR business models and already provides the results it promises.

2.3 IIoT – Industrial internet of things

Finally, the IIoT model will introduce another concept that has exploded in popularity over the years: the internet of things. The term was first mentioned by Kevin Ashton in 1999, more than 20 years ago, and later reiterated[12], as a phenomenon that is here now and that gives computers the potential to observe, identify and understand the world – without the limitation of human-entered data. From that moment, the notion has been extensively developed, but similar to the other cases, it still lacks a clear definition. However, we can describe it as a multitude of devices, services, applications, and platforms that will be highly connected and will communicate in an intelligent manner. In an IoT, all things will exchange, generate, and process data according to the predefined schema (Li, Xu & Zhao, 2015) and will use multiple modern technologies. (Rose, Eldridge & Chapin, 2015) will profile some of the most important, mentioning that it is a confluence of those that make the internet of things concept possible: ubiquitous connectivity, adoption of IP-based networking, miniaturization, or cloud computing being some of the examples. More than that, the authors will enunciate the transformational potential that IoT has: to initiate the transition from passive engagement with devices to the active use of the entire and unlimited internet architecture and processing power.

Referring now to the industrial internet of things, this model will add the production perspective to the characteristics described before. As a result, IIoT will encompass the interconnected elements that will perform all the activities involved in an industry: manufacturing, distribution, production, marketing, or sales. (Sisinni et al., 2018) will develop a way to differentiate the IoT (or the consumer IoT) from the industrial sense of the concept. In that scope, they will use six criteria: the impact, service model, current status, connectivity, criticality, and data volume. To further elaborate, IIoT will aim for evolution, will be machine-oriented, and will use structured and centralized networks (as opposed to ad-hoc). Another important characteristic will be the criticality, the IIoT being mission critical and focused on different parameters such as time, security, and reliability as opposed to the non-stringent character of IoT.

Lastly, as a final, but equally important feature, this new business model will rely on numbers and the overall production improvements will be easy to quantify. In that matter, (Daugherty et al., 2015) estimate that the IIoT field will generate 12$ trillion of global GDP by 2030. In their

12https://www.rfidjournal.com/that-internet-of-things-thing. Last accessed 30/10/2022.

understanding of the concept, the industrial internet of things manages to converge the information and the operations technology, through three capabilities: intelligent machine applications, industrial analytics, and sensor-driven computing. Once again we can see the strong connection between all concepts described above, from the main technologies (sensors, analytics, machines) to the key characteristics (connectivity, access, innovation, automation, and cost-efficiency).

Nevertheless, to differentiate the IIoT and the smart factory, we can state that the latter will be a component of the industrial internet of things or Industry 4.0, without being limited to it. The IoT infrastructure will enrich industrial manufacturing and offer a holistic view of how to integrate information and communication in all product flows. While the smart factory will be based on CPS, the main enabler and confluence between the digital and physical worlds, the IIoT will use the complex capabilities of the internet. To do that, the main element will be the DCS (Distributed Control System), which extensively uses cloud and edge computing functionalities to store and optimize process controls. Lastly, when it comes to the actual implementation of IIoT systems, some industries will prevail in terms of usage and adaptability. The car manufacturing, agriculture, and extracting industries are some of the fields in which extreme precision and connectivity between agents will be the key to successful results.

To sum up, all the advantages of IIoT are becoming more and more evident to companies and external developers that will use it as an optimization strategy and a source of new revenue streams. But besides all its performances, there is however an amplified liability that the IIoT brings to the table: security and especially cyber-security. Software vulnerabilities, the use of obsolete applications, or the lack of authentication practices may lead to breaches and exposure to hacker attacks[13]. However, this is a concern that can be addressed by designing highly encrypted systems, educating employees, and investing in IT resources that can further minimize the risks.

Conclusion

Overall, in this paper, we have revisited the four main industrial moments that inflicted radical change in the way people view and organize all productive and economic activities. The focus has been on the Fourth Industrial Revolution, a period that is happening as we speak and that introduces a multitude of new technologies, changes in paradigms, and societal effects. The 4IR or Industry 4.0 will focus on the extensive and confluent use of modern informational and computing concepts, to enhance the industrial flows and provide immediate results in terms of productivity and efficiency. We have identified five characteristics that are relevant for the 4IR, namely connectivity, access, innovation, automation, and cost-efficiency, all of these describing the new business models of the present and future. The digital platform model, the smart factory, and the industrial internet of things have been discussed from the lens of the five key features, describing shortly their structure, classification, and immediate business advantages.

To conclude, the current period is one in which the frontiers between the digital, physical, and biological worlds are thinner and thinner and the only way to benefit from it is by recognizing the 4IR potential, adapting it to the current business models, and transforming it into immediate and sustainable growth.

13 https://www.tibco.com/reference-center/what-is-iiot. Last accessed 30/10/2022.

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