Chapter 1
Fundamental Concepts of Industry 4.0

Mireia Dilmé i Martínez de Huete

1.1 Introduction

Businesses have always been evolving and innovating, new technologies have always come with challenges and opportunities, and ecosystems have always been changing. So what makes the current era of technological change so different?

It’s in the degree of interconnectedness, the speed of acceleration of change and the very nature of the change itself. Disruption isn’t new, but the speed, complexity and global nature of the disruption is at a scale never seen before.

Businesses in today's competitive environment are increasingly being transformed by technology. Such technology transformation enables companies to grasp opportunities to increase revenues, improve efficiency and flexibility, and deliver more value to end-users.

Technology transformation requires a strategic leader who can engage and examine technology through both a business and technology lens. This book aims to empower users with the basic knowledge of the Industry 4.0 technology domain, its management and strategic implementation.

The present chapter aims to provide a basic understanding to the concepts, trends and key technologies that characterize Industry 4.0. Most importantly, it aims to reflect upon the reasons why enterprises should bet on digital transformation and the change of paradigm in Industry 4.0. This chapter serves as an introduction to the potential that Industry 4.0 unveils. Thus, it can be used as a general framework to then go into further details in understanding the relationship amongst each technology blocks presented in the subsequent book chapters.

M. Dilmé i Martínez de Huete (✉)
Eurecat, Barcelona, Spain
e-mail: mireia.dilme@Eurecat.org

J.C. Chaplin et al. (eds), *Digital Manufacturing for SMEs*
DOI: 10.17639/9vtj-m308

1.2 Introduction to Industry 4.0

If you are a small-to-medium enterprise (SME), it is quite likely that you have already heard the term *Industry 4.0* (I4.0). You may not, however, be persuaded that it is vital to your business. Many SMEs erroneously believe that I4.0 only relates to initiatives pursued by multinational corporations with sizeable budgets like General Electric, Bosch or Boeing. Regardless of the organisation size, the enterprises maintaining this conservative mind-set are actually missing out on the opportunities to increase competitiveness and to innovate. For SMEs in particular, **Industry 4.0 should not merely be perceived as an end goal, but a direction which every enterprise can move toward in some degree.**

What exactly is Industry 4.0? What changes is it bringing? Why does it matter for small and mid-sized industrial enterprises?

1.2.1 Welcome to the 4th Industrial Revolution (Industry 4.0)

Did you know that…?

- 90% of the data in the world today has been created in the last two years alone (IBM research).
- 30% of companies started monetizing their data assets in 2017 (Microsoft research).
- The average lifespan of an S&P 500 company has decreased by 50 years in the last century, from 67 years in the 1920s to just 15 years today (Yale research).
- 86% of CEOs consider digital as their first priority (Microsoft research).
- 76% of millennials believe that innovations their most valuable trait (Deloitte research).

Industrial SMEs need to stay ahead of the ever-changing market requests: hyper-personalised products, shorter product and service life-cycles, global interconnection, the high speed of technological change, and the constant drive for delivering quality at reduced cost.

The rules of the game are changing. How enterprises cope with the transformational challenges is not only by refining their corporate strategies but also creating unparalleled opportunities. What makes the current era of technological change stand out?

- *Interconnectedness:* Now more than ever equipment, personnel and industrial processes are interconnected. Data is gathered and analysed at a global scale, constantly optimizing and facilitating the decision making processes. The physical world is becoming an information system itself. Companies like FedEx, have already stated that *"information is more valuable than any transported good"*.

- *Pace of Change:* Things move at an extremely fast pace in a race where it is hard to keep up. Previously, enterprises had time to track trends and wait for proof of the success of new applications in various settings before adopting them in-house. Now, however, new capabilities are rolled out faster every year, disruptive technological innovations pop up constantly and users are embracing novel technologies at an unrelenting speed.

  For example, as illustrated in Figure 1.2-1, it took about 75 years for the telephone to connect 50 million people. Today a simple iPhone app can reach that milestone in a matter of days.

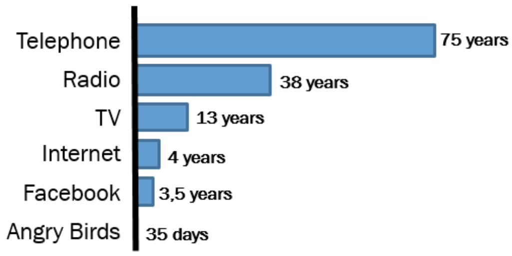

Figure 1.2-1 Time to reach 50 million users [1].

- *Nature of the latest technological change:* Adaptability is key to survival in the age of digital Darwinism, an era in which market drivers and demands are constantly changing. The long-term winners will not be the ones who simply try to make it to the next level but those who constantly adapt. Over the next few years, technologies that have not yet been understood completely by people (e.g. quantum computing) may tremendously influence industrial systems. Enterprises need to prepare their teams, infrastructure and capabilities to successfully embrace the potential of those technologies. This also includes learning to make data-driven and fast-paced decisions and progress within highly uncertain environments.

  As illustrated in Figure 1.2-2, Unicorns, a moniker applied to private start-ups valued at > $1 billion, are no longer so mythical in nature. Technological and digitalized enterprises are leading the unicorn club due to their capacity to operate in uncertain environments and their predisposition to adopt and bet on highly disruptive technology.

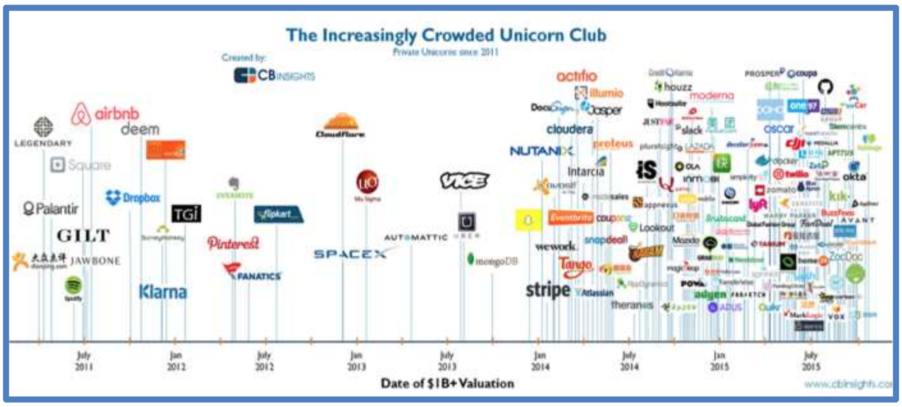

Figure 1.2-2 Technological and digitalised enterprises are leading the unicorn club [2].

These three factors, when combined, result in an unstoppable and self-reinforcing force, boosting and speeding each other up: massive usage of technology accelerates the development and introduction of more technology.

These novel market rules open tremendous opportunities but they can only be met by radical advances in current manufacturing technology. Within this context, Industry 4.0 is a game changer: a key enabler for enterprises to stay ahead in terms of innovation. To achieve this, Industry 4.0 is based on the integration of the company's value chain (suppliers, partners and customers), business and manufacturing processes as well as the adoption of ICT (both hardware and software) to current industrial production systems.

The concept of Industry 4.0 signifies the so-called fourth industrial revolution. Industry 4.0 is derived from the ongoing transformation in the industrial sector preceded by three other revolutions. The first revolution, around 1784, refers to the mechanization of work: incorporating the water/steam engine into mechanical manufacturing facilities. This consisted of the introduction of steam into the tasks that were previously performed by hand.

The second industrial revolution, around 1870, followed the introduction of electrically-powered mass production based on the division of labour. The introduction of electricity into various manufacturing processes made the use of assembly lines possible.

The third industrial revolution, around 1970, was based on the introduction of Programmable Logic Controller (PLCs) – electronics and IT – to achieve further automation of manufacturing. The third industrial revolution was already a huge leap ahead where, in the advent of automation, electronics and computers ruled in the industrial scene. During this era, robots and programmable machinery were increasingly used to perform industrial tasks.

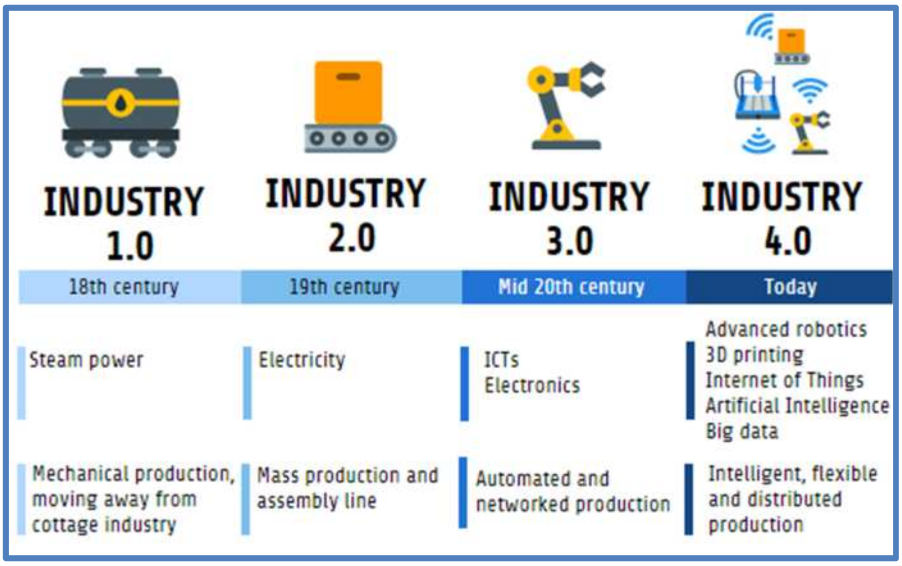

Figure 1.2-3 Evolution from Industry 1.0 to Industry 4.0 [3].

Today, Industry 4.0 is a change of paradigm: not only one but a myriad of cyber-physical technologies are combined to digitally transform industrial activities. Cyber Physical Systems (CPS) are comprised of storage systems, data processing capabilities, smart machines and manufacturing facilities capable of autonomously exchanging information, driving actions and controlling each other independently. An enterprise leveraging Industry 4.0 is not merely investing in production line automation, but it is transforming its production lines through IIoT (Industrial Internet of Things), using cloud technology and applying advanced software and data analytics. Through IIoT, a large number of synchronized sensors provide real time data to an enterprise's computer servers (local or cloud). All this data provides highly valuable information to decision-making processes and it is the key baseline to nourish predictive models which help enterprises to anticipate irregularities in its systems, operations and processes and, hence, actions can be properly taken before errors or major breakdowns occur. This data analysis (if in huge amounts known as Big Data) is the key to maintaining and improving the supply chain, industrial processes and product lifecycle management. Therefore, the result of Industry 4.0 is to create a highly flexible, intelligent, distributed production and service network. The end goal: to pave the way to reach the concept of a Smart Factory that is characterized by adaptability, flexibility and efficiency whilst improving the value delivered to targeted customers.

To ensure that the key difference between the third industrial revolution and Industry 4.0 is fully understood, let's consider the example of a CNC machining centre. If the machine is part of the third industrial revolution era, the tool change can be done automatically but an operator should manually keep track, observe and correct the actions regarding, for example, the spindle speed. However, if the machine is updated to the Industry 4.0 era, the tool changes are also done automatically but, at the same time, the spindle speeds and many other crucial process parameters are automatically recorded by the sensors integrated in the machine. Due to large data processing capabilities, proper settings are automatically calculated by the machine on its own and the process is automatically optimized [4].

1.2.2 Change of Paradigm in Industry 4.0

The first official use of *Industrie 4.0* was coined in Germany around 2011, as a strategic initiative introduced by the German government under the goals to:

1. Identify various trends that were taking place.
2. Encourage projects for the digitalization and introduction of high level technology in manufacturing.

In the following years (mainly after 2014), companies and governments outside of Germany began to step in. The most important move came when the European Commission established a priority: setting a target for the industrial sector to represent the 20% of the European economy up to 2020 thus increasing productivity, competitiveness and overall enterprises added value. To achieve this target, government initiatives, dissemination efforts, specialized financing policies and tools were established.

Industry 4.0 represents a qualitative leap in organization management, control of the entire value chain and monitoring of the entire product lifecycle. In fact, it is a paradigm shift for industries, requiring novel capacities and opening new windows of opportunity – some of which are described in Table 1.2-1.

Change of paradigm in Industry 4.0	
Traditional industry	**Industry 4.0**
Mass production	Hyper-personalisation based on customers’ demands
Large factories to manufacture large volumes of one specific product	Intelligent factories with flexible production lines to produce at competitive costs
Rigid production planning based on stock forecasts	Dynamic production based on market demand
Revenues derived from product sales	Revenues derived from product as a service
Cost minimization	Maximization of ROCE: profitability / capital used.
Labour rigidity	Flexibility in the organization of work.

Table 1.2-1 Maturity model for the adoption of Industry 4.0 [5].

The shift in Industry 4.0 is based on the following principles:

- *Ensuring Interoperability:* The communication capacity of all elements of the factory. There is a need to create common standards that facilitate data flows amongst the cyber-physical systems, robots, corporate information systems, intelligent products and people, as well as third-party systems.
- *Decentralization:* Emphasizing greater autonomy and putting intelligence at the lowest practical level. For instance, implementing cyber-physical elements with the capacity to make decisions autonomously in order to reduce production time and costs. Coordination must be ensured, but a rigid, top-down organization is seen as undesirable.
- *Real Time Analytics:* Massive data collection and analysis (Big Data) in real time that allows the monitoring, control and optimization of processes, facilitating any decision derived from the process immediately.
- *Virtualization:* The ability to generate a virtual copy of the factory through the data collected; in other words, to digitize physical elements. Virtual models of the plant and modelling of industrial processes enable simulation models to perform experiments and better identify and compare alternatives that improve the current production systems.
- *Orientation to Service:* The ability to transfer greater value directly to the customer. This value signifies a better product, novel service or even improved business models.
- *Modularity and Flexibility:* Flexibility and elasticity to constantly adapt to the needs of the industry.

As a result of this paradigm shift, what does an enterprise in the Industry 4.0/Digital era look like?

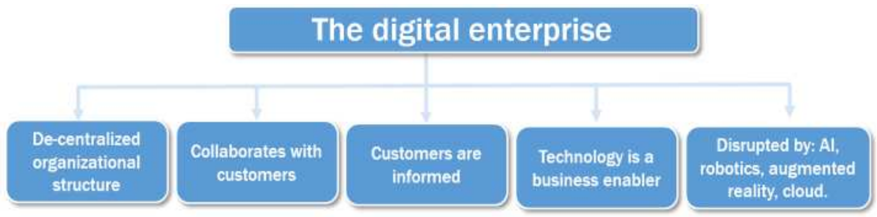

Figure 1.2-4 An enterprise in the Industry 4.0 era. Image rights: Eurecat, adapted from [6].

If successfully implemented, Industry 4.0 principles can impact performance across a myriad of enterprise functions. Several studies, such as McKinsey "Industry 4.0: How to navigate digitization of the manufacturing sector" have quantified this performance gain. The assessment by McKinsey is given in Figure 1.2-5.

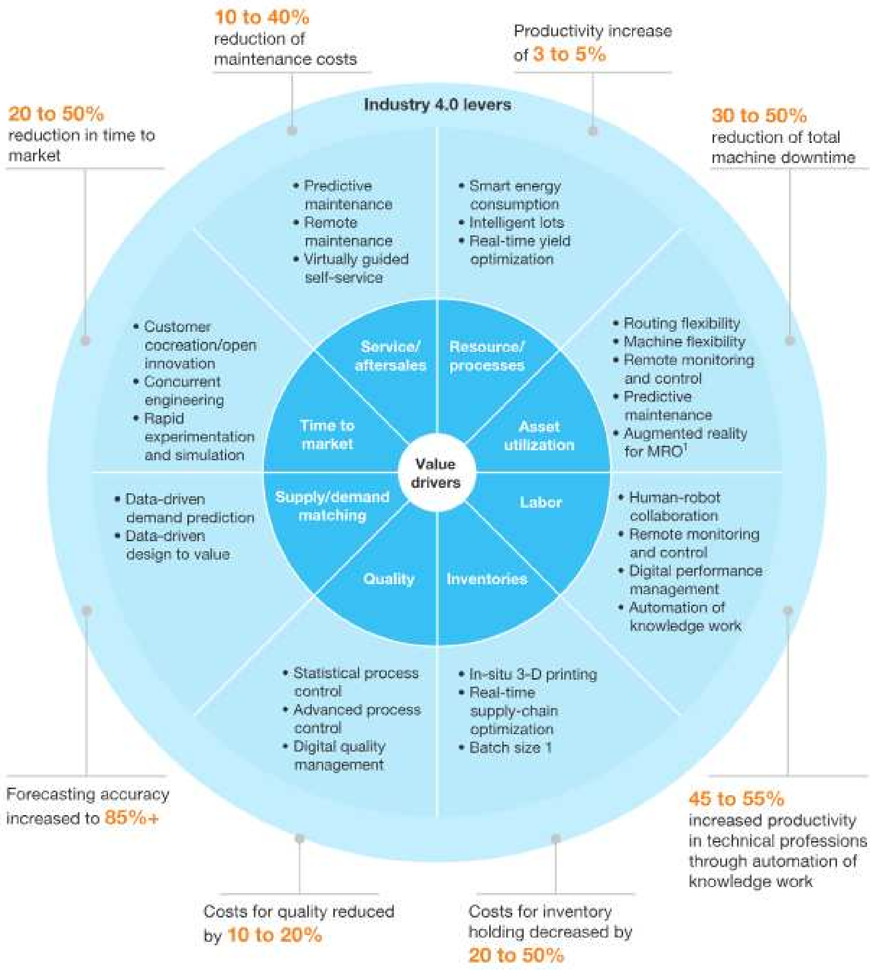

Figure 1.2-5 Performance benefits of digitalization in Industry 4.0 [7].

1.2.3 Industry 4.0, Building the Digital Enterprise

Paperless processes, robotic applications, Internet of Things, digital marketing, digital habits of customers, increasing mobile access. In today's business world everybody is talking about digital technologies and digital transformation. But how does it relate to Industry 4.0?

Some literature defines Industry 4.0 as "*profound transformation of business models by enabling the fusion of virtual and real words and the application of digitization, automation, and robotics in manufacturing*" (Gotz and Jankowska

2017). In short, when planning to transform into a Smart Factory, or be Industry 4.0 ready, a key step is to embrace digitalization. Industry 4.0 requires end-to-end digitisation of all physical assets and integration into digital ecosystems with value chain partners. The ability to generate, analyse and communicate data seamlessly through digitalised processes is key to underpin the Industry 4.0 gains.

In this context, digitisation, digitalization and digital transformation are three terms that tend to be erroneously used as synonyms but have distinctive and important meanings. Let's introduce key definitions to better understand the progressive path towards digital transformation:

- *Digitisation* is the conversion from analogue to digital. Analogue information is encoded and become bits (i.e. digitization of data). Converting handwritten, typewritten or "paper-based" text into digital form is the most simplistic example of digitization. For instance, for a service technician undertaking a field visit to a customer, digitization would imply that the technician is able to easily access all the customer's files, repair reports and product manuals in a digital format wherever he/she is and before, during and/or after field visit. Standalone digitisation doesn't necessary bring monetary benefits (savings or earnings). Nevertheless, it is a must in order to advance towards the digital transformation path.
- *Digitalization* refers to using digital technology in specific operations and the impact it has, generally in terms of cost saving (e.g. digitalization of a process reduces the amount of low-added value human time and effort). In other words, whilst digitisation was merely bringing the information to the digital realm, digitalization is the process of making digitised information work for you. Going back to the service technician example, centralized information about product history and customers (previous issues, replacement history, online manuals, customer contact, etc.) can assist technicians to achieve a first-time-fix contributing towards a smoother and more effective service. Therefore, the technician avoids consulting beforehand an immense amount of obsolete papers to get a deep understanding of the potential solutions and customer pains before the on-site visit.
- *Digital transformation* is a digital-first mentality that encompasses all aspects of business, no matter its nature (if it concerns a digital business or not). Digital transformation leads to the creation of entirely new markets, customers and businesses (capabilities, processes, revenue and operating models). Digital transformation is not something that organisations can implement as individual projects. It rather implies a transversal impact across the organisation: devising new business models, streamlining operations, entering novel markets and disruptively changing how operations are done. As a result, digital transformation can create novel profit streams as well as enable huge savings in the most valuable corporate resources: money and time.

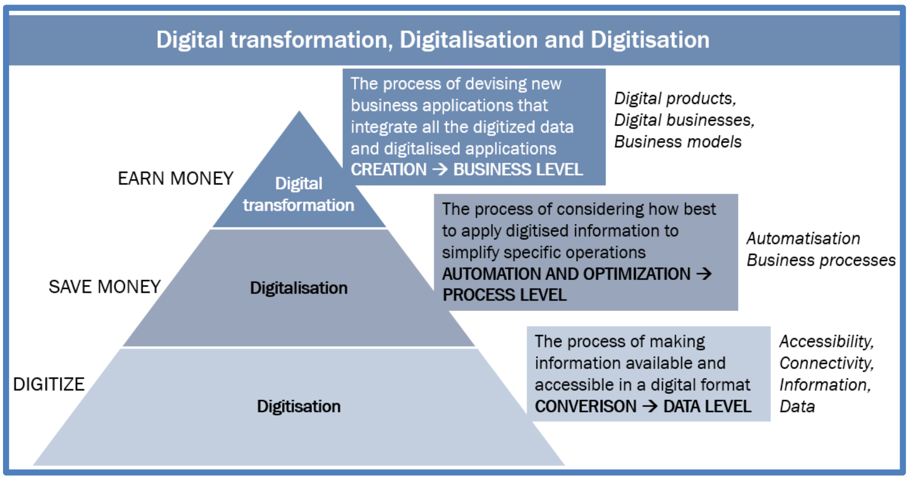

Figure 1.2-6 Digital transformation, digitalization and digitisation. Image rights: Eurecat, adapted from [8].

To summarise, we digitize information, we digitalize processes and roles that make up the operations of a business, and we digitally transform the organisation and its strategy.

1.3 Key Enabling Technologies for Industry 4.0

There is no single list of technologies related to Industry 4.0. In recent years, many consultancies and other organizations have published schemes representing the main technologies, with each scheme deriving from slightly different perspectives.

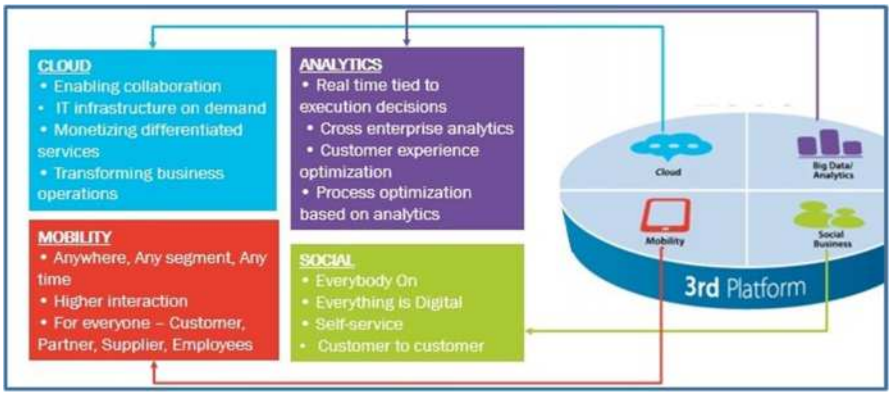

Figure 1.3-1 SMAC forces. Image rights: Eurecat, adapted from [9].

From a digital transformation perspective, in 2012, Gartner introduced the 'nexus of forces' **SMAC (Social, Mobile, Analytics and Cloud)** as the emerging technologies contributing to digital business transformation. In the past few decades the driving forces, behind business agility, were mainly **systems and IT abilities**. However, the current main driver is **information: how information is obtained, managed and used.**

DIGIT-T introduces some of the key technology trends most commonly referred to be leading the road to smart factories, cyber physical systems and end-to-end value chains with Industrial Internet of Things (IoT) and decentralized intelligence in manufacturing, production, logistics and the industry. The technologies defined as the 9 key drivers or building blocks in Industry 4.0 comprise:

1. Autonomous Robots
2. Simulation
3. System Integration
4. Internet of Things
5. Cybersecurity
6. Cloud Computing
7. Additive Manufacturing
8. Augmented Reality
9. Big Data

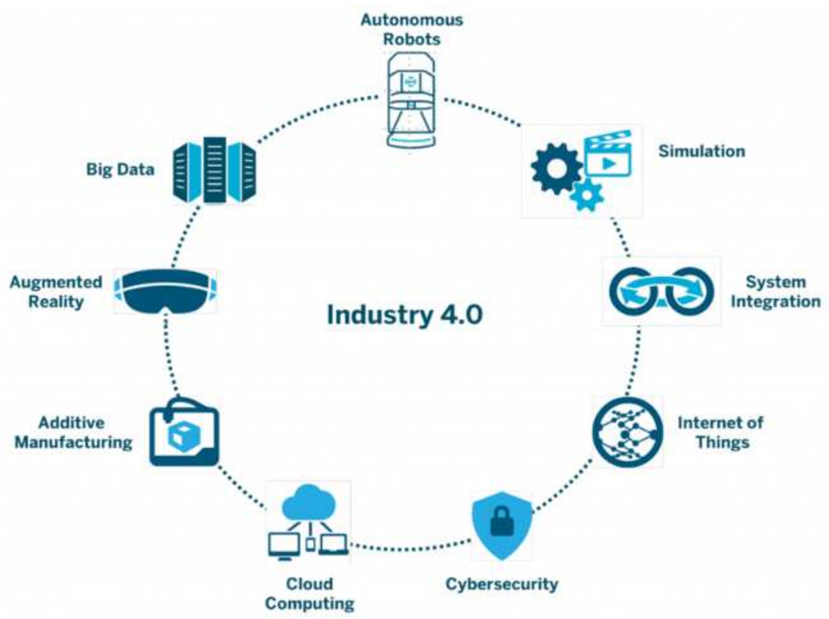

Figure 1.3-2 Key Enabling Technologies in I4.0. Image rights: Eurecat, adapted from [10].

These technologies will now be briefly described.

It is important to highlight that Industry 4.0 is not focused on a specific technology but rather on how to use and combine these technologies to achieve the organizations' planned objectives.

In the following chapters some of these key technologies will be further analysed further to provide a deeper understanding on how and why they are transforming industrial production.

1.3.1 The Internet of Things

The *Internet of Things* (IoT) is the extension of internet connectivity into physical devices and everyday objects. By incorporating embedded electronics, internet connectivity and other forms of hardware (such as sensors) within physical devices, they are capable of communicating and interacting with other physical devices over the internet and can be remotely monitored and controlled.

IoT has many diverse applications in different sectors, such as smart homes, healthy aging, medical and healthcare, transport, etc. The term Industrial Internet of things (IIoT) is often encountered in the manufacturing sector, referring to the industrial subset of the IoT.

Through the IIoT it is possible to connect any element of an industrial plant, transmitting and/or receiving information thus permitting real time monitoring and control and subsequent data analytics. The elements that can be connected include elements inside the plant such as machinery, personnel, tools and raw materials, together with external elements such as vehicles, manufactured products and even customers.

There are several basic building blocks involved in the development of an IoT application:

1. *The Connected Devices:* The physical devices we want to control and manage.
2. *The Gateway:* The element that connects the device to the Internet.
3. *The Internet:* The infrastructure that allows objects and other elements such as computers, servers and data centres to communicate with each other.
4. *The Cloud:* The set of servers and data centres which contain the platform where the information is stored and processed.
5. *The App or Software:* IoT applications usually have an App which allows the users to interact with the platform and visualize the results, control the devices, etc.

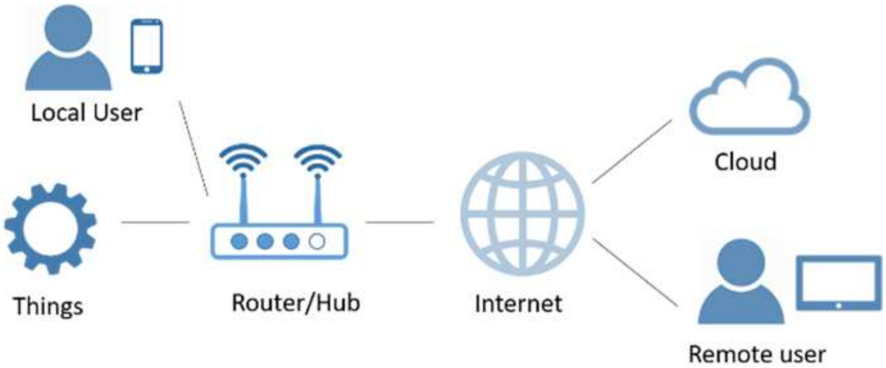

Figure 1.3-3 Elements of IoT. Image rights: Eurecat, adapted from [11].

1.3.2 Analytics and Big Data

Data analytics is the science of analysing raw data in order to make conclusions about that information, capable of permitting businesses to optimize their performance. As illustrated in Figure 1.3-4, data analytics is divided into four different types:

1. *Descriptive Analytics:* Describes what has happened over a given period of time.
2. *Diagnostic Analytics:* Focuses more on why something happened.
3. *Predictive Analytics:* Concentrates on what is likely to happen in the short term.
4. *Prescriptive Analytics:* Suggests a course of action.

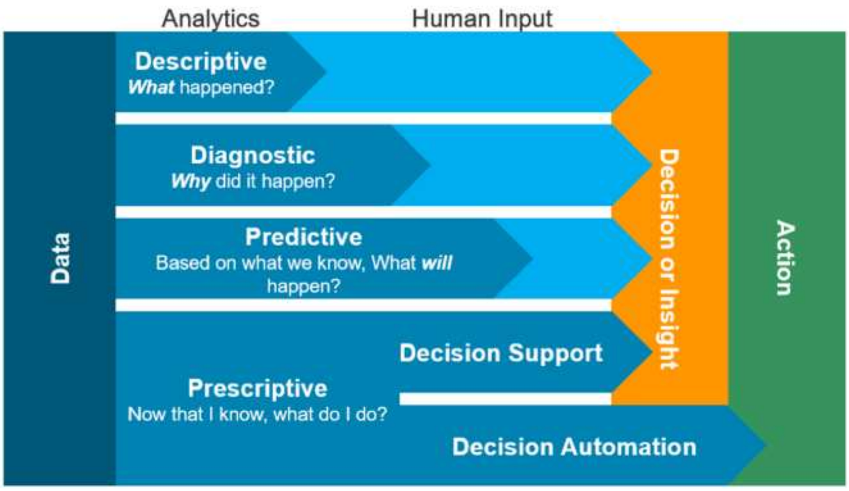

Figure 1.3-4 Types of Data Analytics. Image rights: Eurecat, adapted from [12].

The first type, descriptive analytics, requires more human intervention, given that the person in question must understand the problem, take decisions and finally act. At the other extreme, prescriptive analytics, human intervention is minimal, because the system is capable of suggesting a course of action or even taking a decision by itself.

The term *Big Data* refers to an enormous amount of diverse information which is beyond the capacity of conventional data base systems to manage and analyse in a specific time period.

Big Data is a set of technologies, algorithms and systems designed to collate large quantities of distinct data from which valuable information is extracted by employing advanced high speed analytical systems in real time. In an industrial scenario, the sources of information are multiple and diverse: sensors, equipment and installations, HMI interfaces, applications and information systems, operators, web, social networks, emails, cameras, etc.

Big Data is generally defined by the "5 V's" which refer to:

1. *Volume:* The size of the data generated.
2. *Velocity:* The speed at which the data is generated, collected and analysed.
3. *Variety:* The different types of data collected.
4. *Veracity:* Trustworthiness of the data in terms of accuracy.
5. *Value:* Just having big data is no use unless we have value.

Within this context of Big Data, the application of Artificial Intelligence and particularly machine learning techniques, using mathematical algorithms, allows the development of automatic learning systems with the aim of creating expert recommendation systems.

Machine learning is the scientific study of algorithms and statistical models that computer systems use in order to perform a specific task effectively without using explicit instructions, relying on patterns and inference instead.

Both Big Data and machine learning are key tools and of great importance with diverse uses in industry. They offer many advantages including the support and automation of decision making, the intelligent planning of work within a factory, the auto-configuration of machines according to work orders, the optimization of quality control, and predictive and prescriptive maintenance.

1.3.3 Cloud Computing

Cloud computing implies a paradigm shift in relation to the traditional model which has always been based on progressively acquiring and installing new hardware and which is, as a result, extremely limited due to its cost (e.g. purchase of equipment, software licenses, maintenance, etc.).

Cloud computing allows the use of computing services over a network, usually the Internet, in such a way that the company only pays for the resources it uses, making it technically and economically viable to obtain access to large computing resources.

The model offers important advantages for a company, because it permits it to access only those resources which are required in an agile and cost-effective manner but with the additional advantage of having the capacity of adjusting the scale and/or increasing the resources as is necessary at any given moment.

The cloud-based model is a key element so as to be able to obtain other technologies such as Big Data, machine learning techniques or simulation, and is therefore indispensable for any industry that wishes to adopt the I4.0.

The cloud is also extremely useful to facilitate data sharing across sites and company boundaries. The performance of cloud technologies will improve, achieving reaction times of milliseconds. As a result, machine data and functionality will increasingly be deployed on the cloud, enabling more data-driven services for production systems.

1.3.4 Cybersecurity

Cybersecurity is an indispensable element without which the adoption of I4.0 cannot be successfully addressed. With the increased connectivity that results from Industry 4.0 it is necessary to protect critical industrial systems and production lines from cyber threats.

The three main pillars of information security are Confidentiality, Integrity and Availability, also known as the CIA triad:

1. *Confidentiality:* Only individuals with the legitimate authorisation to access the required information should be permitted to do so. The goal of confidentiality is to prevent sensitive data from being accessed by the wrong people.
2. *Integrity:* This principle seeks to ensure the accuracy, trustworthiness and validity of information throughout its life-cycle.
3. *Availability:* Availability refers to information being accessible to authorised personnel as and when it is needed.

In this sense, it is necessary for companies to adopt security models which respect the sets of relevant existing standards, in particular IEC 62443, a series of standards including technical reports to secure Industrial Automation and Control Systems [13]. On the other hand, it is also important that companies adopt the concept of *security by design* whereby security is taken into account from the early stage of design and conceptualization of new products, processes, systems and services. Therefore, by incorporating security measures and criteria from the beginning, it is possible to minimize and, to a great extent, avoid risks and impact against possible future attacks or accidents as the whole system grows and evolves.

1.3.5 Horizontal and Vertical System Integration

Vertical integration consists of integrating production systems to other areas and departments of a company (e.g. management, sales, finance, human resources, production, etc.). Meanwhile, *horizontal integration* consists of integrating the entire value chain of the product life cycle, thus including an interaction between suppliers, partners and customers.

1.3.6 Augmented Reality

The manner in which one interacts with computers and machines is poised to change in the coming decades. The term *Human-Machine Interface* (HMI) describes the methods in which people interact with computers.

According to Gartner, *Augmented Reality* is the real-time use of information in the form of text, graphics, audio and other virtual enhancements integrated with real-world objects. Creating real-time mixed realities that combine the real world with virtual elements offers extraordinary applications in the industrial environment and facilitates the work and productivity of workers by providing them with the ability to interact and access information of interest, *in situ* and in a systematic way, pertaining to any real element.

Augmented Reality applications are numerous. They include step-by-step instructions on how to assemble a product, field personnel drawing help from experts at remote locations, training, quality control, performance and productivity control, inventory, etc. Augmented Reality technology even permits novice employees to identify problems and perform repairs by following step-by-step instructions.

Another type of HMI is *Virtual Reality*. Augmented Reality alters one’s ongoing perception of a real-world environment, whereas Virtual Reality completely replaces the user’s real-world environment with a simulated one. Virtual Reality is principally employed for training (e.g. in the management of risk situations) and for industrial prototyping.

1.3.7 Simulation

A *simulation* is a model or representative example of the operation of a process, system or object over time. The simulation of products with virtual prototypes permits the optimization of the design phase of new products with a minimization of development costs and a reduction in the length of the marketing period. 3D product modelling techniques also allow the implementation of high-precision quality controls (e.g. metrology) of manufactured products.

The virtual reproduction of a factory (which can include machines, products and humans), whereby the performance of the plant in question is modelled, permits the evaluation in rationale cost and time spans of the suitability of different configuration alternatives in the plant and an analysis of its current response capacity when faced with different predicted demand scenarios.

1.3.8 Additive Manufacturing

Additive manufacturing is based on the creation layer by layer of an object through the use of different materials (e.g. plastic, resin, metal, etc.) with which it is possible to reproduce any 3D model as a real object.

This implies a paradigm shift because it allows:

- The redefinition of manufacturing processes since it allows production without moulds or tools.
- The minimizing or elimination of assembly pieces, thus reducing the amount of material employed to obtain much lighter objects and components.
- Flexibility and rapid adaptation to continuous changes in demand.
- Hyper-personalization of products and the viability of the production of reduced lots.
- The decentralisation capacity which permits production close to targeted customers thus reducing the cost of the associated logistics.

1.3.9 Autonomous Robots

Autonomous *robots* are the application of robotic systems capable of performing tasks with self-sufficiency, without explicit human control. According to the International Federation of Robotics (IFR) the demand for more productivity, the need to work with stricter standards in both industrial processes and the resulting products, the tendency towards mass customization, miniaturization requirements, and the evolution towards shorter product life-cycles has fuelled the use of robotic applications in recent years.

One of the most promising segments in autonomous robots are *collaborative robots* (often referred to as *cobots*). These are industrial robots designed specifically to work alongside humans in a shared workspace and to perform tasks in collaboration with them. These robots are designed with a variety of technical features that ensure they do not cause harm when a worker comes into direct contact. These features include lightweight materials, rounded contours and sensors at the robot base and joints that measure and control force and speed, and ensure these do not exceed defined thresholds if contact occurs.

Collaborative robotics enable manufacturers to improve productivity by using robots to complement human skills, relieving the workers of many non-ergonomic and tedious tasks and can be used to automate parts of a production line with very few changes in the rest of the process.

According to IFR, the market for collaborative robots is still in its infancy. Preliminary results show that, despite the claims of the mass media, less than 4% of the 381,000 industrial robots globally installed in 2017 were cobots. But this percentage is expected to grow in the near future when industry discovers its potential benefits.

1.4 Embracing Technology: Practical Case Studies

As previously highlighted, a company does not need to be a large enterprise or a multinational to benefit from the advantages of technology adoption as long as the technology adopted provide useful solutions to meet needs and challenges. In fact, technology allows the creation and delivery of value not only to customers but also to employees or even to stakeholders in general.

In the previous section Key Technology Enablers were identified. This section considers these in practise using some basic examples which illustrate the impact that technology adoption can have on enterprises' business models and value creation. These examples derive from diverse sectors and applications. On purpose, mostly outside the manufacturing field which could serve as inspiration if the principals are transferred to manufacturing.

1.4.1 Making Use of Open Data – Zaragoza Taxi Initiative

The Zaragoza Taxi Initiative is an example on how to deliver value to both customers and employees.

By using the opportunities opened up by data, some taxi companies are able to improve the performance of their company operations. For instance, in the city of Zaragoza, Spain, a taxi company is using the open data available on the municipality web site to improve its services. Every day the company downloads all public data related to scheduled activities (such as conferences, concerts, sport games, etc.) in the city. The taxi company gathers and processes that information in order to summarize activities, venues, timetable, etc.

The company has also developed an app for its taxi drivers so that they can be sent to the venues at the right time (right after the end of the activity) to pick up potential customers. By doing so the company is able to build value for their drivers to improve their chances of attracting customers and avoid unproductive driving around the city. In parallel, it also brings value for the customers who neither have to call nor wait for the taxis to get to their venues.

1.4.2 Optimizing Inventory Control – Casa Viva

This example shows how technology is able to build and bring value for employees whilst improving company performance is by simplifying internal operations.

Casa Viva is a Spanish home decor retailer with 36 stores in Spain and Andorra. Previously, employees managed inventory control with a purpose specific PDA.

Recently the company has introduced smartphones as the device to check and control all its products. Employees use a regular smartphone (such as the one they have in their personal life) with a built-in app to keep track of the availability and location of different products by merely taking pictures of their labels with embedded codes.

Product data introduction, updating and searching has become much simpler. Besides, in this particular case digital transformation has been characterised as a smooth implementation process since employees do not need to get used to a new technology. Instead, they are using smartphones the same way they use them in their normal lives.

1.4.3 Ground Robot Vehicles for Agriculture – Mas Llunes/ Grape Project

An important issue in business is environmental impact and ways to reduce the amount of chemical emissions.

In addition to robots being used in the manufacturing industry, they are also being introduced into other sectors such as agriculture. Apart from their utility to perform heavy tasks in the field, precision agriculture practices can reduce significantly the environmental impact of farming due to the over application of chemicals.

Mas Llunes, a vineyard company, has introduced unmanned Ground Vehicles (in the context of the EU H2020 GRAPE project [14]) to apply pesticides and fungicides with high precision saving huge quantities of those chemicals and preventing the plantation to be exposed unnecessarily to them. The robot is able to distribute up to 500 pheromone dispensers and allocate them on the vine branches by using an articulated arm. The purpose of dispensers is to spray the pheromones with precision to control plagues.

Advanced sensing capabilities also allow for monitoring at the plant level: the robot can monitor the health status of the vineyard, tracking the colours of the leaves, the dryness and helping the owners take decisions about the plantation and treatments.

1.4.4 Risk Management – IDP / BIM4Safety project

An important issue for companies is risk management. Risk in terms of people safety and in terms of assets security.

For industrial activities in general, and in the construction industry in particular, there is a high risk of injuries and fatalities due to the hazardous placement of people and machinery. There is also concern about people location in case of a major problem when the construction takes up large amounts of space (such as in civil infrastructure construction).

Companies such as IDP, an engineering company, have introduced a combination of BIM (Building Information Modelling) with Internet of Things to improve safety and risk management. BIM are software programmes able to model and manage physical and functional characteristics of places (mainly buildings). They are designed to help architecture, engineering and construction professionals to efficiently plan, design and manage those buildings and their infrastructures.

By combining the functionalities of BIM with the benefits of the Internet of Things companies can integrate within the software, not only the static assets (walls, pipelines, etc.) but also movable assets such as machinery and also workers. Sensors and wearables are attached to people and physical assets to track their location. The real-time localization can be used when needed (e.g. for inventory, in case of danger, layout planning)

1.4.5 Drones for Sewer Inspection – FCC

Decreasing operations and maintenance costs are a key issue for companies navigating today’s markets.

Fomento de Construcciones y Contratas (FCC) is a Spanish company offering urban sanitation services to municipalities and civil infrastructure operators. A drone, which in fact is an unmanned micro aerial vehicle (MAV) equipped with navigation sensors, aims to reduce labour risks associated with the operations and maintenanceactivities as well as to cut maintenance costs, thanks to quicker and more precise inspections.

The drones are also able to reach areas which cannot be reached by terrestrial vehicles, mainly due to dust and rainwater, narrow tunnels, physical obstacles, gases, etc. Drones are ideal for areas difficult to access or dangerous for human beings to work in; these vehicles can work in tunnels up to 80 cm wide and high.

Such drones can inspect 300 metres in 10 minutes. Therefore, it enables teams to inspect almost 2.5 km per day with a drastic reduction on costs and inconvenience, and increasing productivity.

Productivity is also fostered since the amount of data that the drone is able to gather by recording the full inspection on video for later processing is much larger than if acquired by humans.

The drone operates in an autonomous flight mode but it can be seen from the exterior of the tunnels in order to make decisions in case some specific measures and observations are necessary. Since no GPS or external positioning signals are available, the drone has to calculate its position and speed on its own.

1.4.6 Improving Patient Monitoring – Skintemp

Improving the usability and comfort to users is a key issue when it comes to delivering value or utility.

SkinTemp is producing and selling a strip with a sensor, similar to a plaster. That sensor is able to measure the body temperature, glucose level, oxygen saturation in blood, heartbeat rate and even blood pressure. Besides, the user can read (and record) the status and evolution of all those indicators in an app available for smartphones.

Since the strip is a really tiny device it can be worn discretely and comfortably for a long time, it's very convenient for the population in general, but especially for children or elderly people who have more trouble to use a normal thermometer on repeated samples.

1.4.7 Finding Novel Distribution Channels – Homeplus by Tesco

This example considers on value and utility to consumers.

Homeplus is a South Korean supermarket chain owned by Tesco until 2015 when Tesco eventually sold the company to investment fund MBK Partners.

When Tesco and Homeplus landed in South Korea, their main concern was to get a position in the mind of the South Korean consumer and, therefore, how to differentiate themselves from their competitors. Tesco realized that Korea is a hard working society: Koreans stay in the workplace until late. They also realized that Koreans spend a lot of time commuting using public transport, mainly on trains or the underground. As a result, they also spend a lot of time waiting on platforms and don't have much time left for shopping in the supermarket. In fact, when they go shopping, they also experience overcrowded supermarkets and long queues at the counters.

Tesco and Homeplus had the brilliant idea to replicate the supermarkets on the underground platforms so that Koreans could maximize their waiting time in the public transportation system.

Tesco replicated its supermarket shelves by covering the walls with billboards which contained the same layout of products and same packaging designs. Pictures of products also included an embedded QR code so that people were able to buy by simply taking a picture of the code, adding it to their shopping cart and finishing the process with a simple click.

By the time the customers got home the product was delivered to their door. Koreans were able to make the most of their time by transforming their waiting time into buying time.

1.5 Conclusions

Industry 4.0 started in Germany in 2011 and progressively expanded to other European and international markets. The end goal behind any initiative fostering Industry 4.0 is to connect and transform physical systems with cyber technology in order to gain adaptability, flexibility and production efficiency. The current era of technological change differs from previous revolutions not only by the technology itself but also due to the degree of interconnectedness, speed of acceleration and uncertainty of that change. Industry 4.0 is the systematic digitalization of an organization's processes, combining digital, industrial technologies with business transformational processes. We finished the chapter by moving from theory to practice: covering some practical cases of enterprises digitalizing their processes under the I4.0 realm.

1.6 References

[1] Source: Citi Digital Strategy Team.
[2] Source: CB Insights
[3] Lasi, H., Fettke, P., Kemper, H. G., Feld, T. And Hoffmann, M. (2014) 'Industry 4.0.' Business And Information Systems Engineering, 6(4), Pp. 239–242
[4] VIDEO: WHAT IS THE FOURTH INDUSTRIAL REVOLUTION? – World Economic Forum. https://www.youtube.com/watch?time_continue=570&v=kpW9JcWxKq0
[5] Source: Roland Berger
[6] Based on: "Document Model maduresa per l'adopció de la Indústria 4.0 en l'empresa" (SmartCatalonia, created by Eurecat Technology Centre). http://smartcatalonia.gencat.cat/web/.content/02_Projectes/documents/SmartCAT_Model-maduresa-I4.0.pdf
[7] Source: "Industry 4.0: How to navigate digitization of the manufacturing sector." McKinsey Digital 2015. Mckinsey&Company
[8] Source: Own Creation Inspired By: Api Product Management.
[9] Source: What Industry 4.0 Means For Manufacturers. Aethon Graphic Inspired By Boston Consulting Group Discussion On Industry 4.0
[10] Source: What Industry 4.0 Means For Manufacturers. Aethon Graphic Inspired By Boston Consulting Group Discussion On Industry 4.0
[11] Source: Inspired By Http://Archive.Rtcmagazine.Com/Articles/View/106730
[12] Source: Adapted From Gartner Report July 2015
[13] IEC- International Electrotechnical Commission. Publicly available documentation at: https://webstore.iec.ch/searchform&q=IEC%2062443
[14] Grape project website: www.grape-project.eu

“The European Commission support for the production of this publication does not constitute an endorsement of the contents which reflects the views only of the authors, and the Commission cannot be held responsible for any use which may be made of the information contained therein”

Digital Manufacturing Training System for SMEs (Digit-T)
Project ref: 2017-1-UK01-KA202-036807