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Gestión de Proyectos en la Cuarta Revolución Industrial. Proyecto de producción de cerveza.

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ABSTRACT

El objetivo de este documento es encontrar soluciones a los problemas de gestión de proyectos que surgen como consecuencia de la cuarta revolución industrial, que está cambiando la industria tal y como la conocemos y nos sitúa en un punto crítico de adaptación a una nueva realidad que traerá consigo grandes oportunidades y también grandes riesgos. Además, la gestión de los nuevos proyectos 4.0 supondrá un reto de comunicación entre expertos en tecnologías y lenguajes informáticos muy diferentes, por lo que este documento destaca los elementos a tener en cuenta en la revolución tecnológica y estudia cómo gestionar un proyecto en una Smart factory.

The aim of this document is to find solutions to the project management problems that arise as a result of the fourth industrial revolution, which is changing industry as we know it and places us at a critical point of adaptation to a new reality that will bring great opportunities as well as great risks. In addition, the management of new 4.0 projects will pose a challenge for communication between experts in very different technologies and computer languages, which is why this document highlights the elements to be taken into account in the technological revolution and studies how to manage a project in a Smart factory.

KEYWORDS

Cuarta revolución industrial, gestión de proyectos, Smart Factory, metodologías de gestión de proyectos.

Fourth industrial revolution, project management, Smart Factory, Project management methodologies.

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ACADEMIC HONESTY DECLARATION

I declare that the work presented here is, to the best of my knowledge and belief, original and the result of my own investigations, except as acknowledged, and has not been submitted, either in part or whole, for an assignment at this or any other University.

Formulations and ideas taken from other sources are cited as such. This work has not been published.

Albstadt, July 20th, 2021
María Estefanía Rodríguez Martínez

INTRODUCTION

The fourth industrial revolution is reaching previously unknown limits and offers many opportunities not only on an industrial level, but also in other fields from medicine to the way people live. It is expected to mark a turning point in the future of human life as we know it today. As a result, this technological revolution is generating a certain amount of fear and uncertainty about what the future holds. We are at a pivotal moment in deciding what our future as a society will be and in setting the tone for a global revolution.

Following the field of technological revolution at the industrial level, smart factories offer hitherto unattainable possibilities. The technology of the fourth industrial revolution makes it possible to achieve high levels of productivity, detect faults and analyse countless amounts of data in real time, among other things. However, as in all previous industrial revolutions, there are opportunities and risks at all levels. On the one hand, although it is expected to create new jobs hitherto unknown, it also generates great uncertainty for millions of workers who could see their jobs disappear. Furthermore, on an economic level, this industrial revolution will generate large profits, but not for everyone; implementing the new technologies involves a first great economic effort that not all companies can afford, but those industries that do not renew themselves will become obsolete and could disappear or be absorbed by others that have implemented them.

On the other hand, this technological revolution will entail the renewal of numerous industrial control techniques. It will change the way we work and carry out projects. Project management in the fourth industrial revolution could be affected by focusing projects more on 4.0 technologies.

The wide variety of new technologies also means new experts to master them. The realisation of new technological projects will involve the use of a wide variety of new technologies and, with it, the experts who master them. Managing this variety of experts, with different computer languages, will be a challenge for project management in the fourth industrial revolution.

At the University of Albstadt Sigmaringen, a beer production project is being carried out with the aim of improving the quality of beer production and to be a leader in innovation. To this end, the production process is based on Industry 4.0 technology and thus simulates a smart factory. Due to the technical nature of the project and the participation of students from different specialities, we are faced with the aforementioned problem that arises in projects of the fourth industrial revolution: communication between experts in different technologies.

The aim of this document is to study the possible solutions to the problems that arise in the management of this project and the elements to be taken into consideration for projects in the fourth industrial revolution. To do this, the fourth industrial revolution will be studied, the factors that have led us to it and the technologies that make it up, not only at an industrial level, but also in the different fields it covers. Afterwards, project management and the existing methodologies used to manage projects will be presented. Subsequently, these methodologies will be compared in order to know when they should or should not be used. And finally, all the knowledge obtained will be applied to the search for the best solutions for the project in a Smart factory.

The document will be structured as follows: in the first chapter we will go into the fourth industrial revolution in depth, in the second chapter we will study project management and its methodologies, and then in the third chapter we will focus on comparing them, so that in the fourth chapter, focused on the beer production project, we can provide solutions based on what has been analysed, and finally, we will present the conclusion of the work.

1 THE FOURTH INDUSTRIAL REVOLUTION

1.1 HISTORICAL CONTEX

The industrial revolutions that began in the mid-18th century led to the mechanisation of industries and the replacement of human labour and have evolved into what is now known as the fourth industrial revolution. Before delving into this last revolution, we need to know the background that has led us to where we are today.

In the following it fist has to be specified what is meant by the industrial revolution. There are many definitions for this term. David Landes, professor, economist and historian at Harvard, Columbia and Berkeley universities, details that there are at least three meanings to this term. The first definition refers to technological innovations that promote a shift away from artisanal production to factory production, replacing human skill with machinery and animal power with plant-based source energy. The second definition is used to point out an important technological change at some historical point in time or as a result of innovative techniques. And finally, the third definition refers specifically to the period in the 18th century, beginning in England and spreading unevenly across continental Europe, which brought about socio-economic change as a result of mechanisation and industrialisation. (Landes & Antolín Fargas, DL 1979)

Therefore, we could determine that an industrial revolution is a process of change, caused by a reallocation of power and wealth between groups and individuals, based on new technological possibilities and bringing with it strong social changes and a redistribution of economic wealth. In short, it is about changes in three fields: technology, wealth and society, which are intertwined over time and build on each other, leading to a situation that is so different from the initial one that it justifies the use of the term "revolution". (Silva et al., 2019)

A better understanding of the term Industrial Revolution leads to the assumption that the revolutions have taken place throughout history when new technologies and novel ways of perceiving the world trigger a profound change in economic systems and social structures. The revolution represents a radical turning point, changing and influencing all aspects of life. (Klaus Schwab, 2016, pp. 6–7)

The Agricultural Revolution led to an increase in food surplus and quality, stimulating economic and population growth. The introduction of mechanised farming systems generated a surplus of agricultural labour, which was later converted into industrial labour, leading to the migration of the working class, resulting in urbanisation and the emergence of cities. This factor was one of the fundamental pillars for the first industrial revolution.

The first industrial Revolution spanned from about 1760 to around 1840, originated in England. This revolution was driven by the construction of the railway and the advent of the steam engine. The latter, led and enabled production to be mechanized for the first time, marking the beginning of the mechanical production, and further driving social change. The second industrial revolution, which took place between the late 19th and early 20th centuries, spread to other countries such as France, Germany, Belgium, Japan and the United States. Technological and scientific innovations and the advent of new energy sources such as oil and electricity made mass production and the development of the assembly line possible. Production management was improved, production times were reduced, and the quantity of products manufactured at lower prices increased. In addition, the development of means of transport led to the globalisation of the market. The third industrial revolution, beginning in the 1950s, led to the increasing automation of manufacturing and the disruption of industries. In 2007, Jeremy Rifkin, sociologist and advisor to the European Commission and Parliament, established in his book *"The Third Industrial Revolution: How Lateral Power is Transforming Energy, the Economy and the World"* the concept of the third Industrial Revolution, which was approved by the European Commission (Rifkin, 2011). But was in 1996 when Jeremy Rifkin, states in his book "*The end of work"* that: "We are indeed experiencing a great moment of historical transformation towards this third industrial revolution, and we are inexorably heading towards a world of near worklessness. The software and hardware already in place are enabling a rapid transition to a silicon-based civilisation. The unresolved question is how many human beings will be left in the path of the industrial transformation and what the final world on the other side will look like”. (Rifkin, 1996).

1.2 FOURT INDUSTRIAL REVOLUTION

In this section, the concept of the fourth industrial revolution it will be described in depth, followed by a study of the technologies that comprise it and, finally, an analysis of the most important projects that are being developed.

1.2.1 WHAT IS THE FOURT INDUSTRIAL REVOLUTION

The first thing to note is that there is yet no single globally accepted definition to refer to and describe this revolution. This is reflected in the number of completely homologous meanings that exist. One of the best known is the German term "Industry 4.0" but it is not the only one. Some of the most commonly used terms are "Digital Factory", "Digital Manufacturing", "Smart Factory", "Networked Factory", "Integrated Industry", "Digital Revolution", "Production 4.0", "Human-Machine Cooperation", in the United States it is known as "Industrial Internet" or "Advanced Manufacturing", in the European Commission as "Factories of the Future" and in the United Kingdom as "The Future of Manufacturing". (Büchi et al., 2020)

1.2.1.1 HISTORICAL CONTEXT OF THE FOURTH INDUSTRIAL REVOLUTION

The term Fourth Industrial Revolution was first used by Klaus Schwab at the 2016 World Economic Forum, referring to the historic event we are currently experiencing. However, the use of the concept "the fourth industrial revolution" is not new. It was first introduced in 1988 (Rostow, 1988) to identify the processes of transformation and evolution of inventions into innovations by scientists involved in production teams. From then on, the term became associated with the development and application in nanotechnologies. From then on, the term became associated with the development and application in nanotechnologies. (Parthasarathi & Thilagavathi, 2011, pp. 392–398) until 2016, when

Klaus Schwab used it again, but this time to relate it to Industry 4.0 and the technological revolution we are experiencing.

On the other hand, the Industry 4.0 concept emerged in 2011 in Germany due to the German industrial plan "Industrie 4.0". (Kagermann et al., 2013, pp. 1–84) whose aim was to promote the advancement of manufacturing. In 2013 the German government published the document 'Recommendations for implementing the strategic initiative Industrie 4.0' by ACATECH 2013 (Kagermann et al., 2013) causing a worldwide impact that triggered the development of similar strategies in other countries. (Kagermann et al., 2013)(Kagermann et al., 2013)

1.2.1.2 THE FOURTH INDUTRIAL REVOLUTION OR INDUSTRY 4.0

The fourth industrial revolution, or Industry 4.0, is globally associated with the industrial environment. Some authors describe it as a new revolution characterised by the use of cyber-physical systems in the manufacturing environment (Liu & Xu, 2016) the aim of which would be cost-effective mass customised manufacturing with short product life cycles (Veza et al., 2015, pp. 555–560). Moreover, this revolution is characterised by the combination of technological and human capabilities with the aim of improving productivity and wealth in production. Industry 4.0 could even go further and become a manufacturing network in which machines and products interact with each other without human control (Ivanov et al., 2016, pp. 386–402). Erik Brynjolfsson y Andrew McAfee, from the Massachusetts Institute of Technology (MIT), describe it as "the second machine age", 2014, stating that digital technologies manifest themselves especially with industrial automation (Brynjolfsson & McAfee, 2014). Industry 4.0 therefore aims to develop a communication system between production equipment and products based on hyper-connected technology and integrating all production processes (Shao et al., 2019, pp. 1–12).

This revolution, however, is not just about connecting intelligent machines and systems in industries. Its scope is much broader, encompassing technological advances in many different fields such as genetic sequencing, nanotechnology, renewable energies or quantum computing. Indeed, it is precisely this fusion and interaction of different technologies across physical, digital and biological domains that makes the fourth industrial revolution fundamentally different from previous ones (Klaus Schwab, 2016, p. 12). Another major difference with previous revolutions is that, thanks to globalisation, the spill-over effect and diffusion of emerging technologies and innovation is much faster and more rapid (Klaus Schwab, 2016, pp. 12–13). The Fourth Industrial Revolution creates a world in which virtual and physical manufacturing systems cooperate with each other in a globally flexible way.

Moreover, this revolution is manifesting itself in all aspects of society, including technology, production, consumption and business, and is influencing all areas of human life. (Li et al., 2017, pp. 626–637).

Finally, in order to understand why there is no uniform and globally accepted concept to describe this revolution, it is necessary to consider that there is currently a very large number of technologies that make up this revolution, more than 1200 according to (Chiarello et al., 2018, pp. 244–257). In addition, there are many stakeholders - politicians, managers, entrepreneurs, academics and others - each seeking their own benefit and with different needs. And finally, taking into account the speed with which innovations become obsolete nowadays and that there is a wide variety of applications from smart factories, cities, medicine, homes to objects, we can understand why there are so many concepts, meanings, terms, to describe (Büchi et al., 2020, p. 3).
All these factors increase the complexity of establishing a common concept, but what we can determine are the common elements that make up Industry 4.0, which are devices, connectivity, appropriate data, good service orientation, automation systems and connections between the physical and virtual world (Harrison et al., 2016, pp. 1046–1051).

1.2.2 FOURTH INDUSTRIAL REVOLUTION TECHNOLOGIES

In this section, a study is made of the technologies that are shaping this revolution in order to better understand it. The fourth industrial revolution has previously been defined as the fusion of technologies, and their interaction, in physical, digital and biological domains (Klaus Schwab, 2016).

Following this description, we will proceed to classify the technologies that characterise this revolution into digital, physical and biological. The following table shows the division of these technologies:

FIELDS	TECHNOLOGIES AND EXAMPLES
1. DIGITAL	The Internet of Things (IoT)
	Artificial intelligence and machine learning
	Big data and cloud computing
2. PHYSICAL	Autonomous Cars
	3D printing
	Advanced robotics
	New Materials
3. BIOLOGICAL	Neurotechnology
	Genetic Engineering

Table 1. Fourth Industrial Revolution Technologies. Source: (Klaus Schwab, 2016).

The following sections analyse each of these groups, as well as the techniques and technologies of which they are composed.

1.2.2.1 DIGITAL

The first technological field presented is Digital. As can be seen in the Table 1 within this section we find the following technological trends:

- The Internet of Things (IoT)
- Artificial intelligence and machine learning
- Big data and cloud computing
- Digital platform
- Block chain

▪ INTERNET OF THINGS

The term “Internet of Things” was proposed by Kevin Ashton back in 1999 (Ashton, 2009) and he used it to describe the network connecting physical objects in the world to the Internet. However, the idea of being able to connect objects in an intelligent way took root at the end of the 19th century when the first telemetry experiments in history were carried out on Mont Blanc, and later, notable scientists such as Nikola Tesla and Alan Turing continued their research. However, it was not until the end of the 1970s that the first ARPANET network was developed, which became the INTERNET in the mid-1990s. Since 1999, when Kevin Ashton used the term IoT, an exponential growth was experienced, a revolution that has led to the popularisation of wireless connectivity, WIFI, and to a moment of evolutionary effervescence within the IoT.

According to Eduardo Omar Sosa “IoT is considered as a second wave in the ICT industry after the computer, Internet and mobile networks” (Eduardo Omar Sosa, 2012, p. 28). Indeed, as we have been analysing throughout this paper, we are facing a revolution in which the Internet of Things is the fundamental pillar. Further elaborating on the concept, it could be described as a system composed of physical devices (including embedded devices and digital machines with internet connectivity, humans, sensors, etc.) that have the capability to interact with each other autonomously through the use of the internet, in order to improve everything from people's lives, through a country's economy, to industrial and natural resource efficiency. In its simplest form, it can be described as a relationship between products, services, places, etc. and people, made possible through connected technologies and various platforms. (Klaus Schwab, 2016, p. 22).

Currently, the largest volume of interaction with the internet is carried out by humans connecting through their devices. However, in the future this interaction will be carried out by the devices themselves without the need for human supervision.
As a result of this evolution and growth, the number of internet-connected devices per person has increased. According to the Cisco Internet Business Group (IBSG, 2011), in 2010 there were 12.5 billion connected devices and 6.8 billion of the world's population had 1.84 connected devices per person. Thus, before 2010 there were more connected

devices than people. This study predicted that by 2020 there would be a world population of 7.6 billion and 50 billion connected devices at 6.58 connected devices per person. This means that one person would have almost 7 devices connected to the internet.

Figure 1. Connected devices per person. Source: (Cisco, 2011) shows the number of connected devices per person.

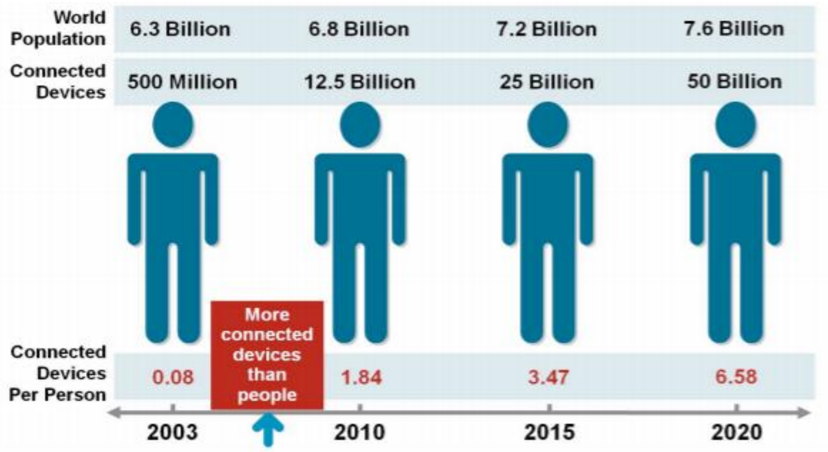

Figure 1. Connected devices per person. Source: (Cisco, 2011)

In March 2020 Cisco published the Cisco Annual Internet Report (2018-2023) (Cisco, U. annual internet report, 2020), which states that 66% of the world's population, 5.3 billion people, will have internet access by 2023 Figure 2. In addition, 29.3 billion connections/devices will be connected, which translates into 3.6 per person and almost 10 per household Figure 3. Of those 29.3 billion, 50% will be M2M connections supporting a range of IoT applications, i.e., 14.7 billion devices on a global scale Figure 4. The following images show the data just mentioned.

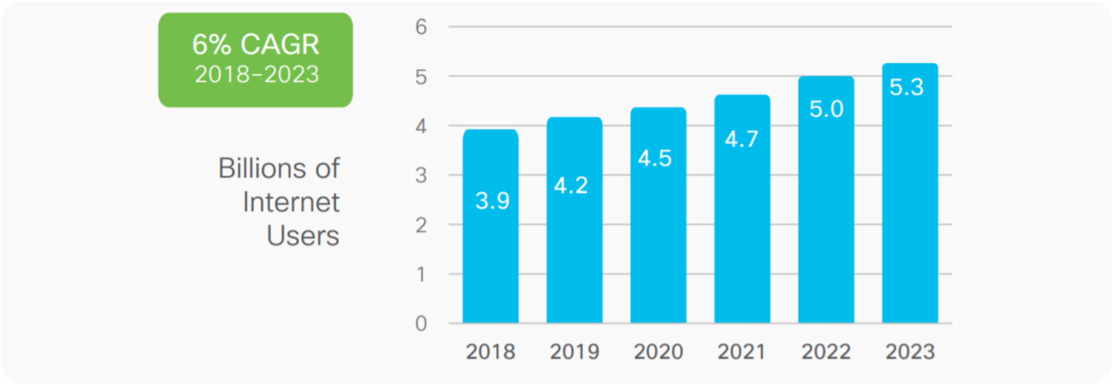

Figure 2. Global Internet user growth Source: (Cisco, U. annual internet report, 2020)

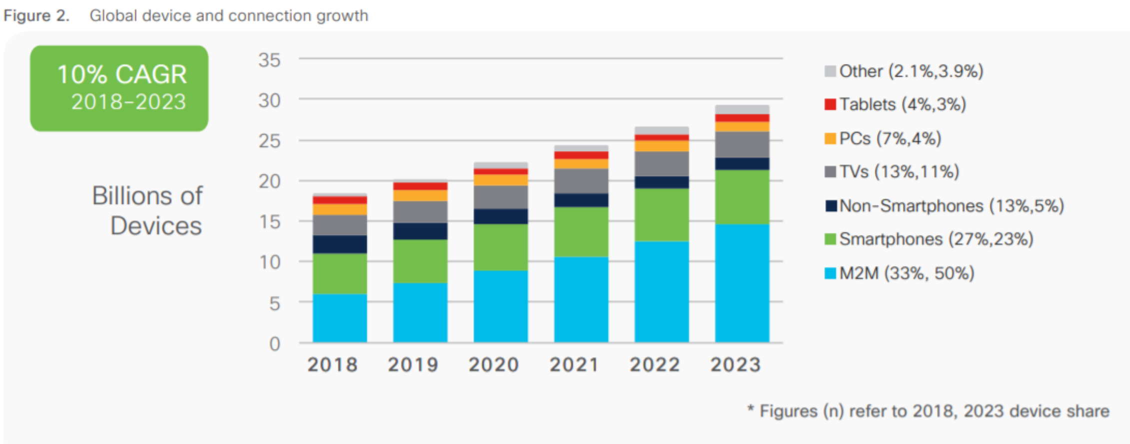

Figure 3. Global device and connection growth. Source: (Cisco, U. annual internet report, 2020)

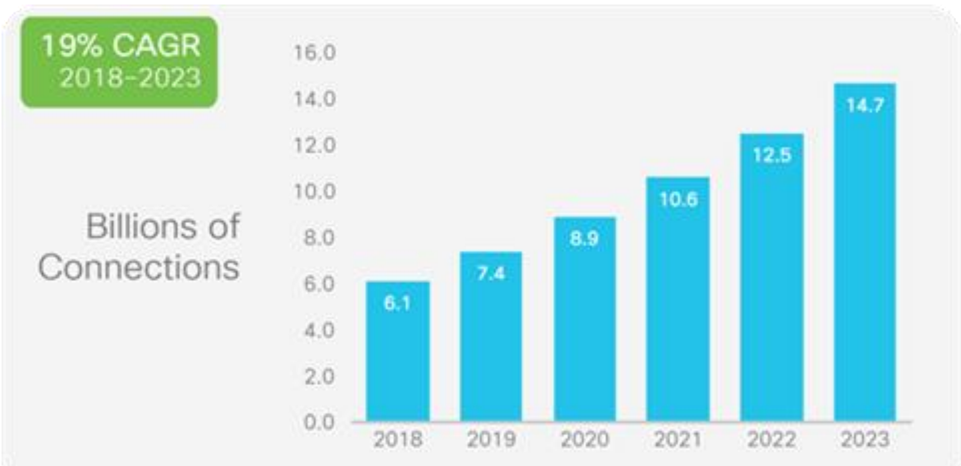

Figure 4. Global M2M connection growth. Source: (Cisco, U. annual internet report, 2020)

HOW IoT WORKS

To understand how IoT works we need to know the basic components of an IoT system (Longo et al., 2018):

- Environment: the physical system of which the IoT system is a part. The IoT system interacts with this environment.
- Devices: in this category we can include sensors, actuators, processors, etc.
- Connectivity: the data collected by all the devices has to be sent to somewhere, and these devices need to be connected to perform that task. The communication can be established by different means, including Bluetooth, Wi-Fi, WAN, etc.
- Data processing: this may refer to several operations that can be performed with all the data collected including reading, checking, identifying patterns and interpreting data.
- User interface: as humans are part of the IoT system, they need a way to read the processed data or to process it themselves.

The devices collect data from the environment. That information is collected and sent for processing. Once it has been processed, two possibilities arise. For those systems that have automated decision-making, instructions are sent back to those or other system devices. For the rest of the cases, the information is presented through some interface so that the people in charge can deal with it.

APPLICATIONS IoT

As discussed above, the fourth industrial revolution will not be limited to industries alone. As an example of this assertion IoT systems have a huge variety of applications (Mukhopadhyay, 2014), including:

- Medicine: a lot of treatments include using activity trackers or similar sensors to look at patients without the necessity of having them at the hospital.
- Automotive: nowadays a lot of vehicles use sensors to improve the user experience while increasing their own efficiency. However, the industry has gone a step further and now it is possible to drive an autonomous car that works thanks to all the information gathered by its sensors. This section will be developed further at a later stage.
- Smart buildings: IoT systems are used not only to monitor what's happening in the building, but also to reduce or optimize the consumption of some resources such as water or light.

- Infrastructure: connected infrastructures using IoT systems could improve certain operations, mitigate risk and carry out predictive maintenance work.
- Military: we can highlight logistic applications such as tracking supplies and equipment in real time or the use of IoT to build "Smart bases". Here we can include reducing some risks with surveillance devices instead of men and a smarter management of resources (water and electricity) to increase the capacity of the base.
- Agriculture: IoT is mainly used to collect data from the agricultural crops and the fields, for instance temperature, humidity, wind speed, etc. This data is later used to improve the quality and quantity of the crops, reduce the waste of water and other resources, optimize the effort required, improve techniques and ways of farming, etc.
- Smart cities: sensors are used to monitor a lot of events that take place in cities such as traffic, pollution, people movements, etc.

BARRIERS AND CHALLENGES OF THE IOT. SECURITY AND SAFETY ISSUES

IoT systems deal with a lot of security issues and one of the goals that every project should include is to keep them safe all the time, because, as we have already mentioned several times, these systems work uninterruptedly. Some of the problems and possible attacks they have to face are:

- Spoofing: which consists of one person trying to cheat the system by making a device act on behalf of others.
- Data tampering: this appears when someone or something tries to manipulate data while the transmission process lasts.
- Eavesdropping: this happens when attackers try to collect the data transmitted by the devices in the IoT system.
- Denial of service attacks: this kind of attack appears when a person or group of people try to collapse the system by sending useless and wrong petitions all the time to a device or a group of devices. The objective they pursue is to flood the system with useless data and force the loss of real information. There are two types:
    - Denial of Service: when a lot of petitions are sent from a single machine or IP address.
    - Distributed Denial of Service: a lot of computers, machines or IP addresses send petitions at the same time.

In order to face this attack, system administrators should configure IoT systems to reject this type of petitions and minimize the consequences in case the attackers should reach the system.

▪ ARTIFICIAL INTELLIGENCE AND MACHINE LEARNING

Andreas Kaplan and Michael Haenlein define artificial intelligence as the "ability of a system to correctly interpret and learn from incoming external data and subsequently use this knowledge to achieve specific tasks and goals through flexible adaptation" (Kaplan & Haenlein, 2019). In addition, artificial intelligence is able to learn from previous situations and provide information that will be used to automate decisions in future complex processes. (Klaus Schwab, 2016, p. 137)

PHASES

The beginnings of artificial intelligence are attributed to Alan Turing who created a machine capable of deciphering codes and learning from it. In the early stages AI was applied to hardware, as in the Snarc (Stochastic Neural Analog Reinforcement Computer) by Marvin Minsky and Dean Edmonds. The next phase focused on computers, e.g., the Mycin expert system, to which neural networks were implemented. The third phase focused on networks; the Authorizer's Assistant of American Express marked a turning point. In the 1990s, the Web led to the creation of several search engines and recommendation systems using intelligent agents. Today, we are at a point in time that could be called "ambient computing", where we live with devices that act as robotic personal assistants constantly taking data and responding to queries and will come to anticipate our needs.

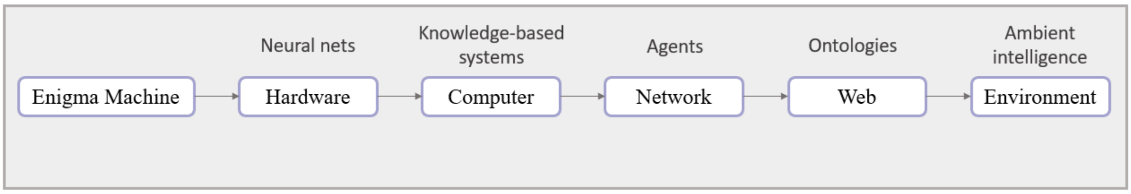

Figure 5. Artificial intelligence evolution Source: Own elaboration

BIG DATA AND CLOUD COMPUTING

According to Gartner big data is “high-volume, high-velocity and/or high-variety information assets that demand cost-effective, innovative forms of information processing that enable enhanced insight, decision making, and process automation” (Gartner, 2020)

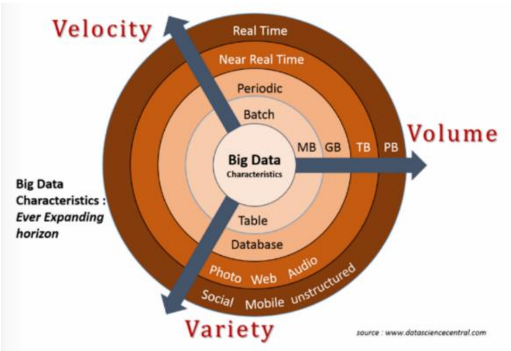

Figure 6. Big Data definition

Nowadays another four Vs can be added related to what people expect from data. These are:

- Veracity: fostering the search for this quality in collected data to obtain reliable information.
- Value: it represents the profitability resulting from data management.
- Variability: it refers to variability in the meaning of the data.
- Visualization: all gathered data must be understandable.

Big Data manages systems that manipulate large amounts of data. However, this term also refers to the use of advanced methods that extract repetitive patterns and useful information in predictive models. In industry, it enables the increase of production quality, saving energy and improving machine service. In the fourth industrial revolution, this technology will lead to the acquisition and detailed evaluation of data from different sources that will be used to simplify decision making.

APPLICATION

One of the main fields of use of big data is decision support systems (DSS). These systems process information to help in the administrative or management decision making process. Big data plays a fundamental role to contribute to the construction of analytical data from operational data. Operational data are selected, processed, and evaluated over time, giving rise to those analytical data that are used to support high-level decisions in the business field.

Big data has many other fields of application that range from medicine to marketing (Srinivasan, 2018) Some of the sectors in which it's already being used with great results are:

- Science: it's being applied to interpret complex systems and improve performance when it comes to carrying out calculations that require large computational capacity.
- Medicine: in this field big data is geared to getting a more personalized and predictive medicine in the future. It takes advantage of machine learning applications and uses different statistical approaches.
- Economy: the use of big data seems essential when it comes to reducing the uncertainty in economic operations. Big data is also being used as a part of the traditional banking system to adapt it to the current needs of customers.
- Service sector: big data is having a huge success here. It's being used to analyze customer behaviour to detect trends and patterns that would help offer better services and adapt them to customers.

HOW TO COMBINE IoT WITH BIG DATA

IoT systems have some features that allow it to be related to big data and make use of processes and tools designed for the analysis of that data (F. Nasaruddin et al., 2017).

IoT systems are a source of continuous information and would generate a big amount of data within a short time and people in charge of that system could apply some big data methods and techniques to manage the system. The goal is to take advantage of this information and be able to use it to solve existing problems and detect problems that were not known before. The analysis of this kind of data will provide several benefits such as Cost reduction. Greater efficiency, expand reaction capacity, minimize data volatility, planning process improvements, among others.

▪ BLOCK CHAIN

Blockchain is a secure, decentralized, and transparent way of recording and sharing data, with no need to rely on third-party intermediaries. The term blockchain refers to a data structure in which information is stored in blocks. These blocks also contain metadata obtained through cryptography and encryption techniques. These metadata prevent data from being repudiated or modified unless every block in the chain is also modified. In other words, we could say that blockchain allow us to keep a distributed and safe database with irrefutable data.

FEATURES

Blockchain technology is based on three main features.

- **Decentralization**: compared to the traditional structures in which information was stored centrally, blockchain proposes the decentralization of information, where all network participants can access the movement log or generate new movements without having to go through a “central entity ".

- **Transparency**: On the one hand, the cryptography used when adding metadata to the blocks gives the participants the necessary privacy. On the other hand, that of transparency, all the transactions and operations are visible, but without giving information that puts privacy at risk.

- **Immutability of information**: This feature refers to the fact that once certain information has been entered in the chain, it cannot be tampered with in any way. This is achieved by encrypting the information using hash functions. The process consists of transforming the information into a hash string that has a certain length regardless of the amount of information that is encrypted. In addition, a very relevant feature is that small changes in the information will make the encryption completely different.

1.2.2.2 PHYSICAL

In this section some examples of the Fourth Industrial physical technologies are presented.

- Autonomous Cars
- 3D printing
- Advanced robotics
- New Materials

▪ AUTONOMOUS CARS

This technology is still in an experimental phase. Autonomous vehicles interpret data and make decisions, and there is even the possibility of an external higher control taking over the operation of the vehicle in certain circumstances. These vehicles know the mapping, read the signs and interpret the traffic data. By defining the origin and destination of the vehicle, the vehicle chooses the trajectory and executes it. However, there are other autonomous vehicles such as trucks, drones, planes and boats. As technologies such as sensors and artificial intelligence progress, the capabilities of all these autonomous machines will increase at a rapid pace.

The problems are associated with several aspects: The vehicle is not able to interpret the reactions of other drivers, which may handicap some of the decisions made. Legislation does not yet recognise the use of autonomous vehicles in a general way, requiring the presence of a driver. In the event of an accident, the responsibilities of each party are not defined, and may affect the owner and/or driver of the vehicle as well as the insurance company or the manufacturer/programmer of the vehicle. Given the potential of a vehicle to cause damage, it is essential to ensure that there is no external control capable of manipulating the vehicle.

▪ 3D PRINTING

Additive manufacturing or 3D printing consists of creating a physical object by printing a 3D digital model or design in layers. Until now, subtractive manufacturing was carried out in reverse, removing layers of material until the desired model was obtained. Therefore, 3D printing allows manufacturing companies to print with less material, less tooling, more product customisation, at a lower cost and faster than subtractive manufacturing. In addition, this manufacturing has the potential to create very complex models without the need for tools (Klaus Schwab, 2016, p. 147). It is being used in a wide range of applications, from large (wind turbines) to small (medical implants). But the current focus is on automotive, medical and aerospace applications. 3D printing has limitations of size, cost and speed, but as these are overcome, it will be included in other electronic components such as printed circuit boards and even human cells and organs. In addition, researchers are already working on 4D printing that would lead to a new generation of self-modifying products that would respond to environmental changes and could be used to make clothing or footwear, as well as for healthcare as implants designed to fit the human body (Klaus Schwab, 2016).

- **ADVANCED ROBOTICS**

Robots have evolved so much that they are increasingly used in all sectors for a wide range of tasks. New technologies are creating more flexible and adaptable robots, which, thanks to the evolution of sensors, are able to better understand their environment and develop responses accordingly. Human-machine collaboration is becoming an ever-closer reality and is already taking place in many industries. (Klaus Schwab, 2016)

- **NEW MATERIALS**

This technology refers to materials that are light, strong, recyclable and adaptable. Moreover, these new smart materials are capable of self-repairing, cleaning and even returning to their original shape, and could be a breakthrough in the fight against climate change and have a major impact on new forms of manufacturing. (Klaus Schwab, 2016)

1.2.2.3 BIOLOGICAL

Biotechnology harnesses cellular and biomolecular processes to develop new technologies and products for a range of uses, including developing new pharmaceuticals and materials. Researchers in Stockholm, for example, are working on what is being touted as the strongest biomaterial ever produced. Secondly, medicine. Robots and high tech can fast track a cure for paralysis. Moreover, 3D x-ray analysis allows scientists to fabricate a piece of living bones ready por implantation in 3 weeks. And being able to use genome editing in order to understand changes that lead cancer bring us closer to find a cure.

1.2.3 IMPACT AND CHALLENGES

“From the perspective of human history, there have never been a time of greater promise or potential peril” –Klaus Schwab.

Like its precursors, the fourth revolution is generating both enormous economic potential and fears about the changes it implies. Living through a revolution is not easy, the models of the past are obsolete while the future ones are not fully developed and socially accepted. (Silva et al., 2019, pp. 7–8).

Klaus Schwab warned of the situation we find ourselves in at the World Economic Forum, adding that we are currently on the brink of an economic revolution that will impact and change our lives, jobs and even the way we relate to each other. He warned that the scale, scope and complexity of this revolution will result in a transformation unlike anything humanity has experienced before (Klaus Schwab, 2016)

Precisely how and when people and societies adopt new patterns of behaviour and thinking will determine, to a large extent, how they will be affected by economic and technological change (Silva et al., 2019)

In this section we will study the main repercussions that this revolution will have, both the positive aspects that it will bring and the challenges and negative impacts that could affect us, focusing on three main points: business, the economy and the labour market.

1.2.3.1 COMPANIES

One of the biggest benefits of the fourth industrial revolution for businesses will be improved productivity. The basic principle is that companies will be able to create smart grids that will be able to control themselves, along the entire value chain. (Perasso, 2016)

The automation of actions will reduce production times, costs and failures, increase workers' safety and allow them to spend their time on actions that really add value. The application of new technologies facilitates data-driven decision making, improves product quality, enables the creation of new products and services of higher quality, making manufacturing more flexible and the flow of information between different departments and stakeholders more efficient.

However, not everything is positive. According to experts, only those who are able to innovate and adapt will benefit, and as these are recent technologies, they will require a great economic effort that not all companies will be able to afford. Moreover, the cyber risks involved in automating a company mean that cybersecurity must be stepped up, the digital divide and technological dependence and the difficulty of finding people specialised in the new technologies are some of the major challenges that companies will have to face.

1.2.3.2 ECONOMY

The fourth revolution has the potential to raise global income levels and improve the quality of life for entire populations (Klaus Schwab, 2016) . Each revolution has led to increased productivity and industrial quality, as well as socio-economic growth for countries. The fourth industrial revolution will add $14.2 trillion over the next few years and intensify globalisation that will positively affect technological impact. (Schäfer, 2018, pp. 5–7). Proof of economic improvement is the increase in GDP after each industrial revolution shown in the figure.

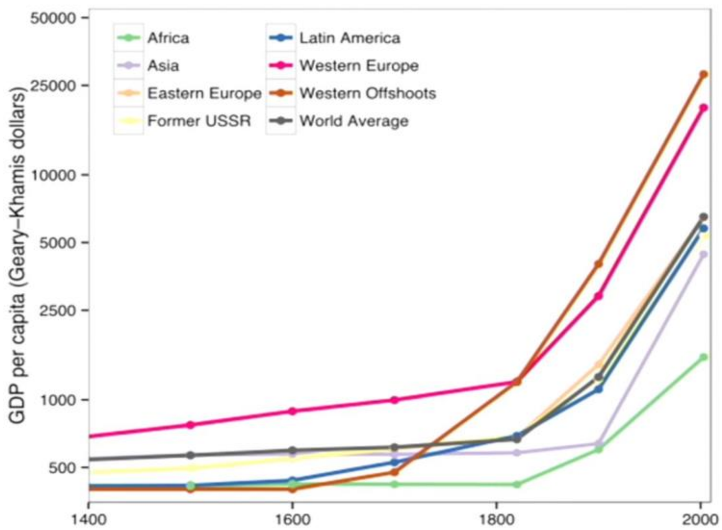

Figure 7. GDP after the industrial revolution Source: TEDX

On the other hand, it also suggests that it will increase wage inequality and lead to geopolitical clashes. The WEF itself acknowledges that "the benefits of openness are at risk" from protectionist measures, especially non-tariff barriers and global trade regulations, which have been exacerbated since the 2007 financial crisis: a challenge that the fourth revolution will have to overcome if it is to deliver what it promises.

1.2.3.3 LABOUR MARKET

Employment is one of the great challenges of the fourth industrial revolution, which will drive the creation of jobs that are difficult to replace in terms of technology, creativity and leadership, but nevertheless, many jobs will disappear. In 2020, the World Economic Forum (WEF) presented the report entitled "The future of Jobs", which analyses the destruction and creation of jobs in the coming years as a result of automation. Many jobs involving repetitive and precise tasks have already been replaced by new technologies and the automation of processes (*The Future of Jobs Report*, 2020).

1.2.3.4 REFLECTIONS

As discussed above, each revolution has led to an increase in industrial productivity and quality, as well as socio-economic growth for countries. However, the wealth of countries has not been equitable for all, the revolutions have also brought inequality. The goal in the fourth industrial revolution is not only to achieve higher production but to do so with sustainable development that advocates sustainability and inclusive social and economic development (United Nations, Geneva, Switzerland/2014)

Finally, I would like to end this topic with Klaus Schwab's thoughts on the subject:

"First, I feel that the required levels of leadership and understanding of the changes underway, across all sectors, are low when contrasted with the need to rethink our economic, social and political systems to respond to the fourth industrial revolution. As a result, both at the national and global levels, the requisite institutional framework to govern the diffusion of innovation and mitigate the disruption is inadequate at best and, at worst, absent altogether.
Second, the world lacks a consistent, positive and common narrative that outlines the opportunities and challenges of the fourth industrial revolution,

a narrative that is essential if we are to empower a diverse set of individuals and communities and avoid a popular backlash against the fundamental changes underway." (Klaus Schwab, 2016, p. 13)

2 PROJECT MANAGEMENT

2.1 PROJECT CONCEPT

A project could be defined as a temporary endeavour composed of a set of interrelated activities carried out in a coordinated manner by a person or entity to produce a unique product, service or result and to achieve goals and objectives, usually to achieve benefits, change or added value. (Nokes & Kelly, 2007). Being temporary, it has a defined beginning and end in time, (usually with time constraints and often with funding or staffing constraints). According to the (PMBOK, 6th edition) a temporary effort that is undertaken to create a unique product, service or result. (*A Guide to the Fundamentals of Project Management (PMBOK Guide), Sixth Edition*, 2017, p. 4). A temporary, single, multidisciplinary and organised effort that is carried out with deliverables subject to predefined requirements and constraints (*Individual Competence Baseline Für Programmmanagement*, 2017). Moreover, it is a complex and dynamic system, (consisting of multidisciplinary activities), which needs to be acted upon throughout its life, in order to achieve the objectives of: scope, time, cost, quality and stakeholder satisfaction. (Pajares et al., 2017, pp. 125–126).

The main objective of a project is to satisfy a client's need. (Gray & Larson, 2018, p. 6). Furthermore, the main characteristics of a project are the following: Having an established objective; a defined life span with a beginning and an end; the involvement of several departments and professionals; doing something that has never been done before; specific time, cost, and performance requirements. (Gray & Larson, 2018, pp. 7–8).

2.1.1 DIFFERENCE BETWEEN PROCESS, PROJECT AND PROGRAMME

A common conceptual problem is to refer interchangeably to process and project. It is important to stress that projects should not be confused with day-to-day work (processes). Although both are aimed at achieving a goal, processes usually involve doing the same work or simulating it repeatedly, whereas a project is carried out only once and when completed results in a new product or service.

Recognising the difference is important because too often resources can be depleted in day-to-day operations, which may not contribute to the organisation's long-term strategies that require innovative new products. (Gray & Larson, 2018, pp. 8–9). Moreover, in practice, managing these different production approaches requires the development of different technical skills and management strategies. (Cattani, 2011)

Another common conceptual misconception is the use of the terms project and programme as synonyms. A programme is a group of interrelated projects designed to achieve a common goal over a long period of time. Each project within a programme has a project manager. The main differences are in scale and duration. Programme management is the process of managing a group of ongoing, interdependent and interrelated projects in a coordinated manner to achieve strategic objectives. While each project retains its own objectives and scope, the project manager and team are also motivated by the overarching programme objective. (Gray & Larson, 2018, pp. 8–10).

2.2 PROJECT MANAGEMENT

The official definition provided by the Project Management Institute (PMI) states that project management is the use of knowledge, skills and techniques to execute projects effectively and efficiently. It is a strategic competence for organisations, enabling them to link project results with business goals to better position themselves in the marketplace. Project management is understood as the application of knowledge, skills, tools and techniques to project activities to meet project requirements. (*A Guide to the Fundamentals of Project Management (PMBOK Guide), Sixth Edition*, 2017, pp. 10–11).

The official definition provided by the Association for Project Management (APM) states: project management focuses on controlling the introduction of the desired change. This involves: understanding stakeholder needs; planning what needs to be done, when, by whom and to what standards; creating and motivating the team; coordinating the work of different people; monitoring the work being done; managing any changes to the plan;

achieving satisfactory results. (*Directing Change*, 2008, pp. 3–5). Project management, then, is the application of knowledge, skills, tools, and techniques to project activities to meet the project requirements.

2.2.1 PROJECT MANAGEMENT CONTEXT

Although projects can be found in ancient civilisations, such as the Egyptians, Greeks and Romans, it was not until recent years that project management was developed as a discipline with the development of the CPM (Critical Path Method) and PERT (Project Evaluation and Review Techniques) methods by the United States Department of Defence, in the context of the Polaris Programme.

As a discipline, project management has mostly been developed by professionals who bring together and structure the knowledge, skills, tools and techniques (that) can increase the chances of success in many projects (*A Guide to the Fundamentals of Project Management (PMBOK Guide), Sixth Edition*, 2017). In fact, the most commonly used management methodologies have been developed by international professional associations, such as the Project Management Institute (PMI) and the International Project Management Association (IPMA). These professionals study the tools of project management in different areas with the aim of increasing the scope and quality of project management; providing a forum for ideas, applications and solutions; stimulating the use of project management for the benefit of business and the public; collaborating with universities and other educational institutions; fostering academic and industrial development; and engaging in international networking. (Lledó & Rivarola, 2010, p. 16).

Other popular bodies of knowledge, guidelines and methodological frameworks include PRINCE2 (Projects in Controlled Environments), developed and widely used by the UK Government, the P2M (Program and Project Management for Enterprise Business Innovation) of the Project Management Association of Japan and the APM Body of Knowledge of the British Association for Project Management (APM), among others.

2.2.2 PROJECT MANAGEMENT METHODOLOGIES

Having listed several of the most internationally recognised organisations, we will now introduce the different methodologies and standards for project management in complex environments. We will classify the methodologies as follows:

TRADITIONAL METHODOLOGIES	AGILE METHODOLOGIES
PMBOK IPMA PRINCE2 PM2[1] WATERFALL	EXTREME PROGRAMMING SCRUM KANVAN LEAN DEVELOPMENT

Table 2. Classification of project management methodologies. Source: (Matovic, 2020)

2.2.2.1 TRADITIONAL METHODOLOGIES

PMBOK

Conceived as a manual or guide developed by the Project Management Institute (PMI). The PMBOK covers the tasks, processes and qualities necessary for the successful management, administration, direction and execution of business projects. Although according to Michael DePrisco, Chief Operating Officer of PMI, the seventh edition will be published this year in August 2021 (Michael DePrisco, 2021) the current edition is the sixth, which encompasses project management techniques and tools in 49 processes. Depending on the stage of the project, these processes are divided into five groups (initiation, planning, execution, monitoring and control, and closure) and 10 knowledge areas (integration, scope, time, cost, quality, human resources, communication, risk, procurement, and project stakeholder management). (*A Guide to the Fundamentals of Project Management (PMBOK Guide), Sixth Edition*, 2017).

[1] Although it is not recognised as a traditional methodology, it is based on and includes best practices of PMBOK, IPMA, PRINCE2.

On the other hand, it is important to take into account the characteristics that are known at the moment of the new edition. This edition will be more flexible in project management, will be more principle-based than process-based, will focus on results rather than client deliverables, and will encourage proactive, innovative and agile practitioners in response to change, whether it is the disruption of a new technology, competitors or a health crisis such as COVID-19. (Michael DePrisco, 2021).

- PMBOK PROCESS GROUPS

As mentioned above, the PMBOOK groups the processes into 5 groups, which are set out below:

- BEGINNING

  This group contains 2 processes: completion of the charter and identification of stakeholders. The objective of this group is mainly focused on the definition of the new project.
- PLANNING

  Includes 24 processes that focus on defining and establishing the objectives and the strategy to be implemented for the successful achievement of these objectives.
- EXECUTION

  Includes 10 processes that are dedicated to ensuring compliance with the execution of the work defined in the previous group, planning. In this group are the processes to which the largest number of resources are allocated.
- MONITORING AND CONTROL

  Made up of 12 processes that analyse and regulate the project process, in order to identify and control possible risks so that they have the least possible impact on the execution of the project.
- CLOSURE

  This last group is made up of 1 process whose objective is to formally end the project, in addition to resolving all contracts, evaluating the completed project and studying the lessons learned and possible improvements.

  The following Figure 8 shows the interrelation between processs, and the processs that form each group.

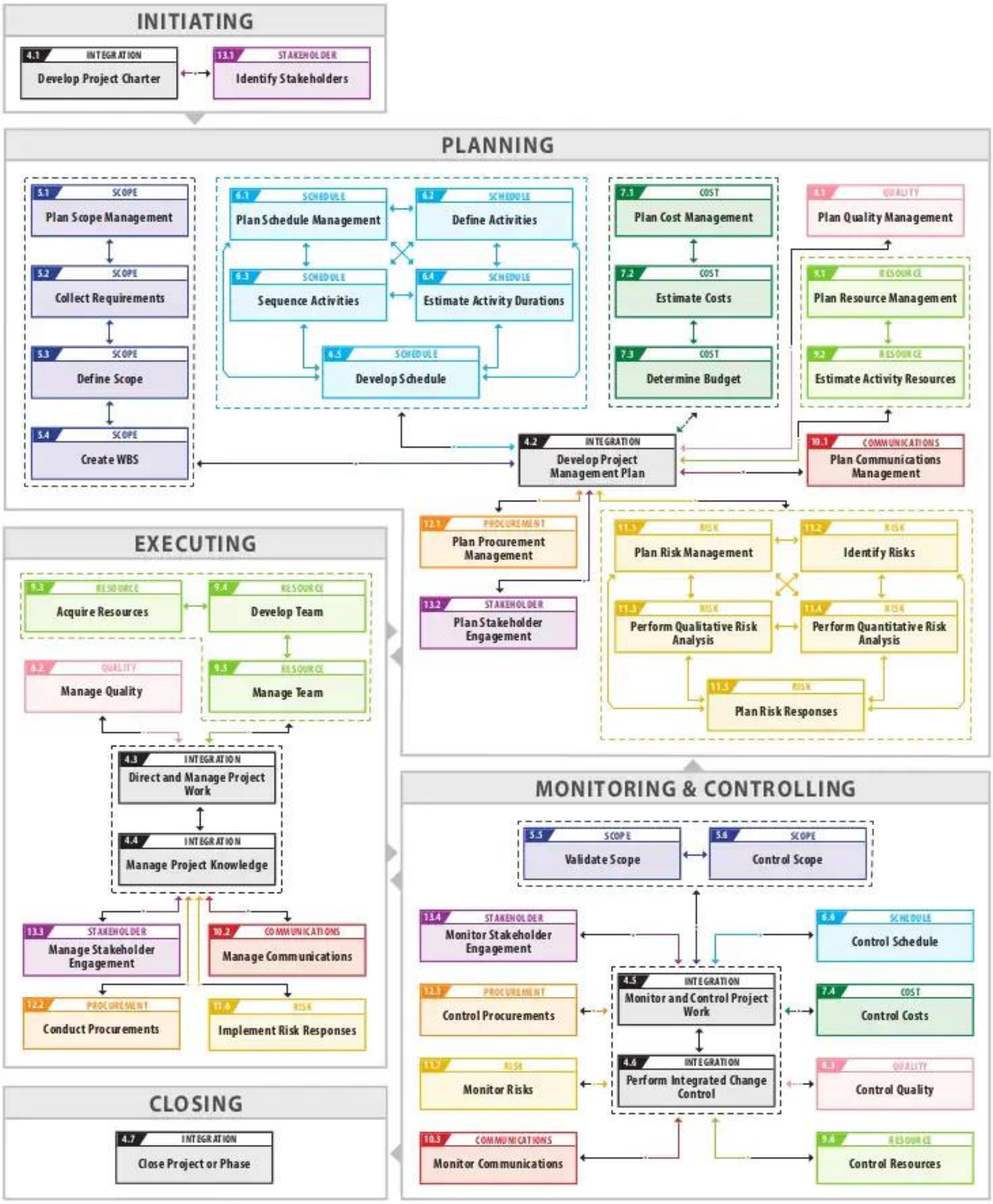

Figure 8. PMBOK Flow process. Source: (Vargas, 2021)

Below shows the lifecycle in which these groups of processes are carried out:

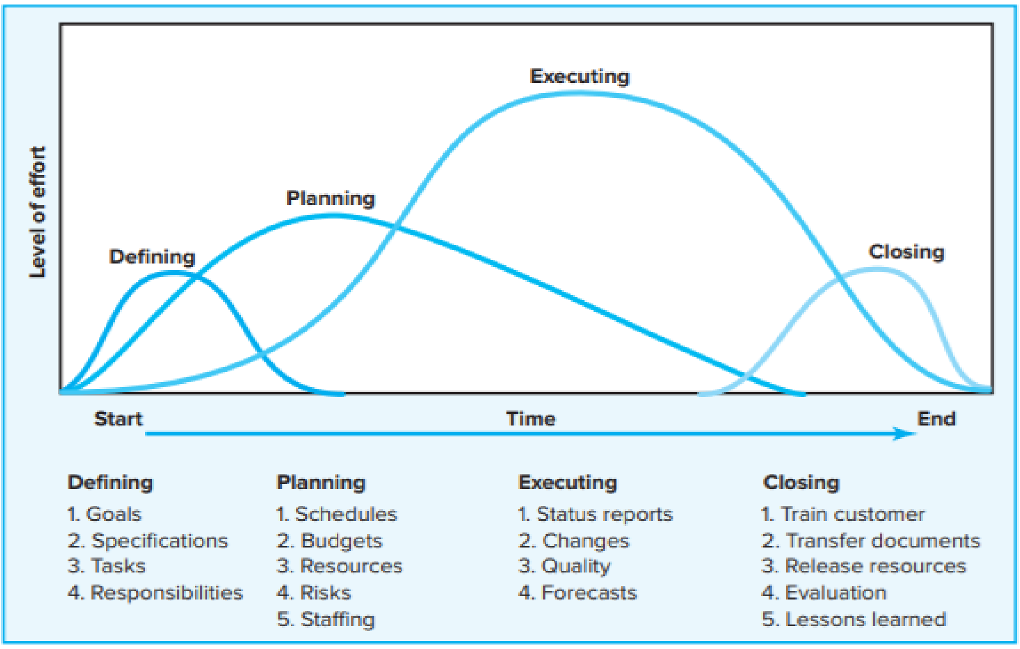

Figure 9. PMBOK Process lifecycle. Source: (Gray & Larson, 2018)

- PMBOK KNOWLEDGE AREAS

As mentioned above, the PMBOK (*A Guide to the Fundamentals of Project Management (PMBOK Guide)*, *Sixth Edition*, 2017) contains 10 knowledge areas, which are detailed below.

- INTEGRATION MANAGEMENT

  Area related to project management. It integrates all the knowledge areas with each other and manages the interdependence of the whole project. It defines the management, coordination and administration criteria.

- SCOPE MANAGEMENT

  Establishes the scope of the project. The objective of this knowledge area is to ensure that the project includes all the work required to carry it out. It determines the parts that are included and excluded considering all the activities and processes involved, compiles the project requirements and details the necessary deliverables to be executed to achieve the objective.

- PROJECT SCHEDULE

  This area includes all the actions to be carried out for the timely completion of the project. It defines the actions and their interrelationships and duration. By means of chronograms such as the Gantt tool, the execution of the project is controlled.
- COST MANAGEMENT

  Consists of planning, estimating costs per activity, budgeting, obtaining financing and, based on the time schedule, managing and controlling costs to complete the project within the established budget.
- QUALITY MANAGEMENT

  Establishes how to ensure compliance with project requirements and deliverables. To do this, it uses indicators that determine whether the quality obtained is optimal or whether action must be taken to correct incidents.
- RESOURCE MANAGEMENT

  This area of knowledge identifies, estimates, acquires and manages the human and material resources necessary for the execution of the project.
- PROCUREMENT MANAGEMENT

  Purchase and acquisition of products or services that need to be obtained outside the project team, as well as management of subcontractors and establishment of agreements and contracts.
- COMMUNICATIONS MANAGEMENT

  Establishes communication mechanisms and monitors them with a focus on effective information exchange from all parties involved in the project, in order to ensure all information needs are met without misunderstandings. This area is often underestimated, yet it makes the difference between projects and, if not carried out correctly, affects many areas of knowledge.
- STAKEHOLDER MANAGEMENT

  One of the most important areas of the project, in fact, the identification of stakeholders is carried out in the first processes of the project. Apart from the identification of stakeholders, both internal and external, the aim is to define their interests in order to satisfy them and have a positive impact on the project, leading to its success.

- RISK MANAGEMENT: possible risks, both current and future, are identified, classified and analysed and a possible response is planned in case they occur. In addition, they are monitored for their evolution and to discover possible new risks. Failure to carry out this area of knowledge could lead to project failure.

ICB

The ICB (IPMA Competences Baseline), is another manual or guide made as a basis for the IPMA certification programme. Unlike the PMBOK, which focuses on processes, the IMPA promotes project management centred on professional competencies, which it defines as "individual competence is the application of knowledge, skills and abilities to achieve the expected results" (*Individual Competence Baseline Für Programmmanagement*, 2017). The IMPA, whose current version is 4.0, considers 3 competence areas: People Competencies (personal and interpersonal competencies), Practice Competencies (methods, tools and techniques used in projects) and Perspective Competencies (interaction with the environment and project strategy and governance).

PRINCE2 PRojects IN Controlled Environments

Another project management method focused on managing, controlling and organising the project. This method is applicable to all types of projects, from software development and digital transformation to construction projects.

It is based on 7 Themes, 7 Principles and 7 Processes, which combined serve to create an easily replicable guide. (AXELOS, 2017). The following Table 3. PRINCE Organisation Source: (AXELOS, 2017) summarises the issues, principles and processes:

Topica (WHAT)	Principles (WHY)	Process (HOW)
Business Case	Business justification	Start-up
Organisation	Learning from experience Defined roles and responsibilities	Starting a project
Quality	Management by phases	Project management
Plans	Management by exception	Controlling a phase
Risk	Product focus	Management of product delivery
Change	Adaptation to the environment	Management of phase limits Closing of a project
Progress	Learning from experience Defined roles and responsibilities	Starting a project

Table 3. PRINCE Organisation Source: (AXELOS, 2017)

PM²

A methodology endorsed by the European Commission, which offers solutions and benefits through effective project lifecycle management. PM² has been created with the needs of EU institutions and projects in mind but is transferable to projects in any organisation. The PM² Methodology is built on Project Management best practices and is supported by four pillars (European Union, 2021).

The basis is market best practices that support 4 pillars (Figure 10), namely Governance, Lifecycle, Processes and Tools. The spirit of the PM2 methodology is defined in detail in the PM2 Philosophy, which includes PM2 best practices and provides a common set of beliefs and values for PM2 project teams (Kourounakis & Maraslis, 2018).

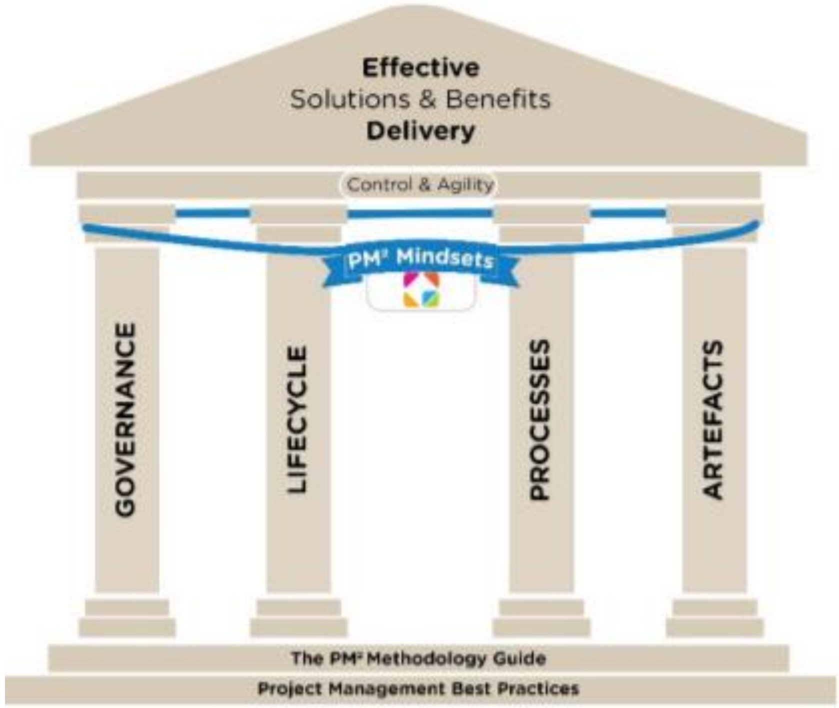

Figure 10. PM² Pillars. Source: (European Union, 2021)

As mentioned above, PM² is based on the best practices of other methodologies such as PMBOK. Proof of this is the following Figure 11 which shows the project lifecycle, very similar to the one shown in Figure 9.

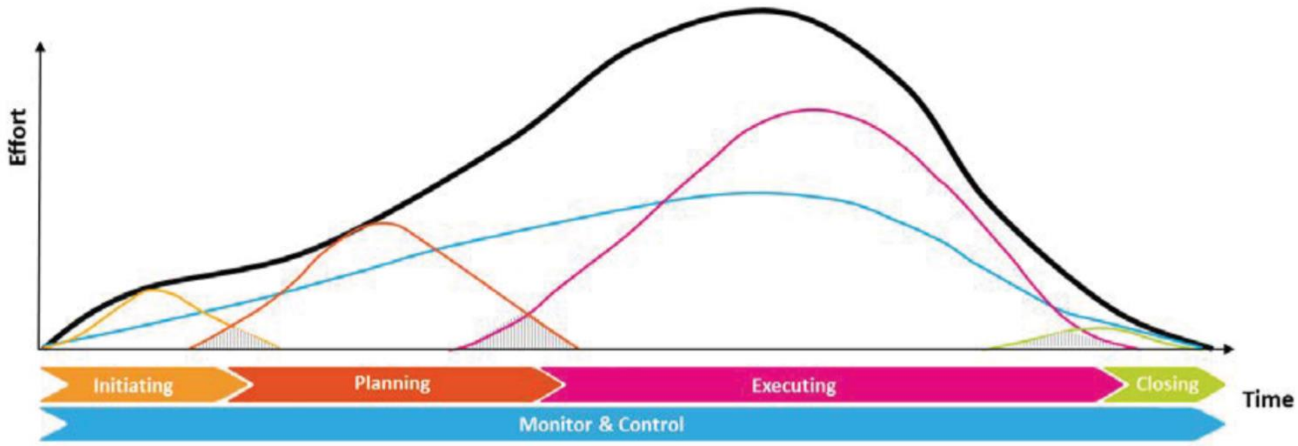

Figure 11. PM² lifecycle. Source: (European Union, 2021)

The following Table 4. PM^2 project phases shows a summary of the concepts of each: phase of the project.

Project Phase	Description
1. Initiating	Define the desired outcomes. Create a Business Case. Define the project scope. Get the project off to a good start.
2. Planning	Assign the Project Core Team (PCT). Elaborate the project scope. Plan the work.
3. Executing	Coordinate the execution of project plans. Produce deliverables.
4. Closing	Coordinate formal acceptance of the project. Report on project performance. Capture Lessons Learned and post-project recommendations. Close the project administratively.
Monitor & Control	Oversee all project work and management activities over the duration of the project: monitor project performance, measure progress, manage changes, address risks and issues, identify corrective actions etc.

Table 4. PM^2 project phases. Source: (European Union, 2021)

WATERFALL

This methodology is a classical model developed and prioritised in the life cycle process (Bhavsar, 2021, pp. 23–24). This model, presents a sequential development (Balaji & Murugaiyan, 2012, p. 27). This methodology is distributed in several stages. The output, or end of the previous stage will form the input for the next stage, and so on. (Alshamrani & Bahattab, 2015, p. 106). An example of this can be seen in the following image:

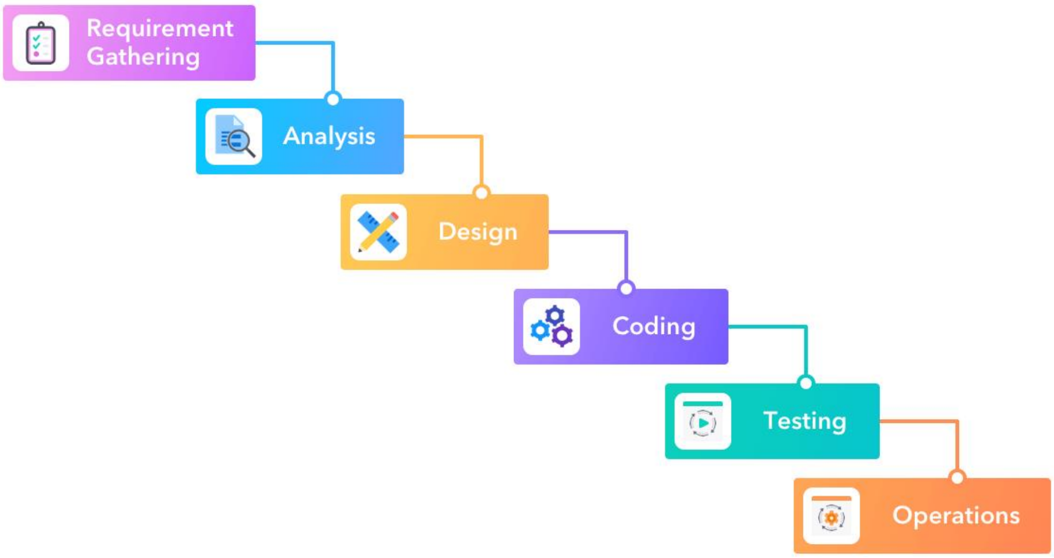

Figure 12. Waterfall methodology. Source: (Infinity, 2021)

- WATERFALL AREAS

As it could be seen in the Figure 12, the waterfall areas are:

AREAS	DESCRIPTION
REQUIREMENT GATHERING	○ The collection of customer and stakeholder requirements is the first step of this methodology. It is the first step in organising and planning the entire project without the involvement of the customer. ○ The requirements must be documented detailing the necessary characteristics and data.
ANALYSIS	○ As discussed above, the input to this area is the output of the previous area, so the input to the analysis stage is the requirements document from the previous stage. ○ The requirements document is analysed and the models that will be used to design logical and theoretical solutions are developed.
DESING	○ The input to this section are the solutions elaborated in the previous analysis. ○ In this section the decisions made earlier are modified if necessary and all technical requirements are reviewed. ○ After all this has been done, a concrete plan is obtained in which the theoretical solutions have been translated into concrete specifications.
CODING	○ Following the concrete specifications of the previous section, the actual code is developed.

TESTING	○ With the actual code written in the previous stage, the code is examined for defects and bugs. ○ Sometimes this stage may take us back to coding to ensure zero defects. ○ If there are no defects, the final stage is passed.
OPERATIONS	○ With the application finalised in the previous stage, the implementation of the application will be carried out in this area. ○ Support, updating and maintenance of the application is included.

Table 5. Areas of waterfall methodology. Source: Own made following (Bhavsar, 2021; Infinity, 2021 Alshamrani & Bahattab, 2015; Andrei et al., 2019; Balaji & Murugaiyan, 2012; Haworth, 2021; Morton, 2011)

▪ ADVANTAGES AND DISADVANTAGES

To summarize in the following images the advantages and disadvantages are shown:

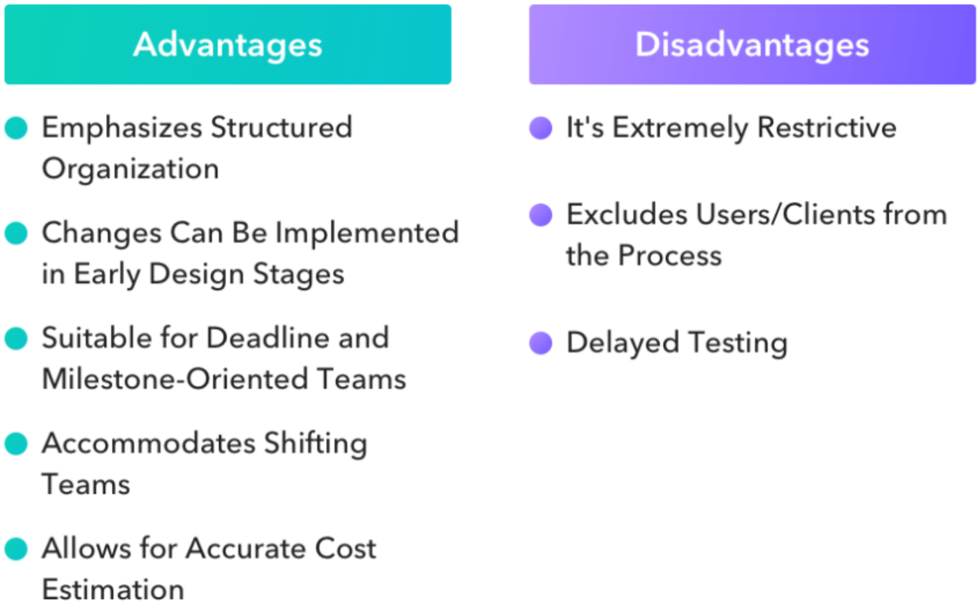

Figure 13. Advantages and disadvantages of waterfall methodology. Source: (Infinity, 2021)

2.2.2.2 AGILE METHODOLOGIES

Throughout the 21st century, the use of agile methodologies for the development of computer software has been spreading. The basis of all of them is the establishment of work cycles, at the end of each of which a more and more complete functional product will be obtained (incremental processes). Agile methodologies are those that allow the way of working to be adapted to the circumstances of the project, achieving rapid responses and flexibility to adapt the project and its development to the circumstances of the environment. The aim is to increase the client's confidence by involving them in the process, cooperating with the team and obtaining results on a regular basis.
The benefits of this methodology for the companies that apply it are to manage their projects in a flexible, autonomous and efficient way, reducing costs and therefore increasing their performance. These methodologies are characterised by reducing the large amount of documentation that is generated in projects that follow traditional methodologies, continuously adapting to the circumstances and needs of the client and presenting an incremental development of a product.

In February 2001, a meeting was held in Snowbird (Utah, USA) with seventeen critics to establish principles for improving software development. As a conclusion of this meeting, a document called the Agile Manifesto was produced (Beck et al., 2001). The Agile Manifesto is a set of rules, standards and guidelines that a methodology must comply with in order to be considered agile. Although the Agile Manifesto assesses that all parties involved in the development of a project are important, sometimes certain elements meet and need to be prioritised.

In fact, there are different types of methodologies that have been nuanced according to the needs of the type of project, but all of them are guided by the Agile Manifesto, which includes these four premises:

- Individuals and interactions over processes and tools.
- Working software over comprehensive documentation.
- Customer collaboration over contract negotiation.
- Responding to change over following a plan. (Beck et al., 2001)

This methodology is widely used in software development, but it is also interesting for development projects in which different iterations are needed to reach the result. In fact, one of the main advantages that we find in the use of agile methodologies is its adaptation to the needs of the project. (J. Highsmith & A. Cockburn, 2001, pp. 120–127).

In addition, there are a number of advantages when applying this type of methodology, such as customer satisfaction, by involving them in the decision-making process of the project, being informed at all times of the progress of the project and its difficulties, in order to obtain a more accurate opinion of the approach to resources, the improvement of the involvement and motivation of the team is plausible because they are equal participants in the same, knowing at all times the status of the project, and by performing different iterations, we increase the efficiency and speed of the work done, eliminating any unnecessary features.

The advantage we get from the implementation of agile methodologies in complex projects is that we do not have to wait until the end of the project to get the result of the project, but we will also work by functional, iterative and incremental deliveries, through which the client will be able to know how the product is growing and how it is being built.

The following are the best-known agile methodologies currently in use:

EXTREME PROGRAMMING, *XP*

The XP methodology is an agile methodology dedicated to software development. It is one of the most successful today and is dedicated to the development of short-term projects with a small team size. The methodology consists of rapid (or extreme) programming, whose particularity is to have the end user as part of the team, which is considered one of the requirements for success in the project.

- EXTREME PROGRAMMING HAS THE FOLLOWING CHARACTERISTICS:
  - Iterative and incremental development: Small improvements that follow one after the other.
  - Continuous unit testing: Often repeated and automated, including regression testing (to discover bugs in functionality). It is advisable to write test code before coding.
  - Group programming: it is recommended that development tasks are performed by two or more people in the same position. In this way, the code is reviewed and discussed while it is being written, which ensures an increase in quality that is more important than possible loss due to unproductivity.
  - Bug fixing: Before adding new features, it is important that all bugs are fixed. This is solved by increasing the number of deliverables.
  - Integration of the programming team with the client/user: It is recommended that a representative of the client works together with the development team.
  - Code refactoring: This consists of rewriting certain parts of the code to improve its readability and maintainability, without modifying its behaviour. Tests must ensure that no bugs have been introduced in the refactoring.
  - Shared code ownership: Instead of dividing the responsibilities for the development of each module in different working groups, this methodology promotes that any member of the team can correct and extend any part of the project. Frequent regression testing ensures that potential bugs are caught.
  - Simplicity in the code: This is the best way to make things work. XP claims that it is better to start with 'simple' development and have to do extra work if improvements are needed, than to use complex software and code, where making changes is really complicated.
  - Simplicity and communication are extraordinarily complementary. With more communication it is easier to identify what should and should not be done. The simpler the working system, the simpler the communication in the working team, which leads to more complete communication, especially if the team of programmers can be reduced.

- XP ROLES

Although the number of roles has evolved since its initial conception, and varies depending on the product or project being developed, the original proposal of the XP methodology included the following:

- Customer / User: This is the person in charge of writing the User Stories, which includes all the desired functionalities. He/she must also participate in the functional testing of the product to validate its implementation. He/she categorises the tasks by difficulty and/or importance, deciding which ones should be developed in each work cycle. There is only one client or user per project within the team who, if necessary, must act on behalf of as many people as may be affected by the solution.
- Coach: The Coach ("trainer") is responsible for ensuring that the XP methodology is being implemented correctly. He/she needs to know the XP procedures in depth to lead the team during the development of the project.
- Big Boss: The Big Boss (Manager) has the main function of being the link between the customer and the development team. He/she mainly performs coordination tasks.
- Programmer: Programmers are the main developers of the product. They write and implement the system code. They must be in constant communication with the other members of the team, as the performance of the rest of the activities depends on their work.
- Tester: The Tester (test manager), performs the functional tests in conjunction with the client on a regular basis. It is usually a single person, who must be in constant communication with the programming team to solve possible code errors.
- Tracker: The Tracker must continuously evaluate the status of the project, comparing it with the estimates made both at the beginning and during the course of the project. He/she reconsiders objectives, deadlines and resources in each work cycle to improve the estimates.

All of these roles are present in virtually any project where this methodology is used, although it is common for the same person to assume several of them simultaneously. It is common for several of the functions of Tracker, Coach and Big Boss to fall on the same member of the team.

SCRUM

SCRUM is a working methodology for the development and maintenance of products of any complexity. It is one of the most representative agile methodologies currently used. Its initial focus was for use in software development projects, although its principles are easily adaptable to any context or area of knowledge. The Scrum methodology is a framework based on iterative and incremental product development, where the different versions validated by the team are periodically formalised, facilitating the development of optimal solutions adapted to the needs of the end customer. All of this is based on teamwork, with different specific profiles, and on constant meetings, normally scheduled, making this one of its fundamental pillars.

The general structure of the work process according to Scrum starts with the registration of customer requests, which is carried out by the "Product Owner", who is the intermediary between the end customer and the development team. With all the needs registered, we proceed to plan how to proceed and the resources to be allocated, as well as defining the regular and partial deliveries to be made, called "sprints". After planning, everything agreed between the team and the Product Owner is recorded and the different iterations for product development begin, which are managed by a "Scrum Master", who would be a manager and facilitator of the team. During the development phase, short daily meetings (maximum 15 minutes) are held to redirect the work plan. At the end of each sprint, the entire team meets with the Product Owner to review the status of the officialised version, to warn of any difficulties, of the objectives achieved and to suggest actions to increase the final performance of the product. All versions are registered in order to have the necessary traceability. Once the whole process is finished, a retrospective meeting is held, which must be attended by the entire Scrum Team, with the objective of recording the lessons learned, possible improvement actions and hard points of the project.

This philosophy can be applied to any type of project in which development is carried out, whether IT or mechanical, simply by varying the phases and in some cases the execution times. But with the sole objective of obtaining a product that satisfies the end customer by optimising resources and maximising the performance of the final product.

- **SCRUM ROLES**

The SCRUM lifecycle is composed of three main roles:

- **Product Owner**

  This is the representation of the customer within the work team. Their main responsibility is to clearly express the customer's need within the Product Backlog. It does not necessarily have to be the customer himself, or someone external who defends his interests. Most commonly, it is a member of the team, who acts as requirements engineer, whose main mission is to access all the information and get first-hand knowledge of all the client's needs, and then transmit it to the rest of the team members.

- **Development Team**

  The development team is made up of the personnel responsible for carrying out tasks through Sprints. It must be made up of qualified professionals who are capable of providing solutions to the Product Owner's needs. It is very important that it is a self-managed and organised team. Although the functions within the Development Team are very varied, the team members are known as developers. This is done to simplify roles and avoid hierarchies within the team, so programmers, testers, analysts... will have the same importance.

- **SCRUM Master**

  Is responsible for ensuring that the SCRUM methodology is being applied correctly during the project, ensuring that the team works according to the corresponding theory, practices and rules. He takes on the role of moderator, so he is not responsible for giving orders or knowing how the software works. His main function is to help the Development Team to understand the client's needs, expressed through the Product Owner, and to organise the project according to the principles of the SCRUM methodology.

- **PHASES AND PROCESSES**

The life cycle of a project development using SCRUM methodology can be divided into five phases:

1. INITIATION

First of all, the Product Owner is going to define a document with all the needs that the client needs to cover. This document is called Product Backlog. It must contain all the ideas, needs and requirements that will fulfil the customer's formal request.

Once it is correctly known what has to be done, it is necessary to identify the Scrum Master and the stakeholders of the project, as well as to form the team with the developers that will participate in it, forming the Development Team.

2. PLANNING AND ESTIMATION

The Product Owner has to state the customer's needs to the Development Team and the Scrum Master. This is done in a meeting called Sprint Planning Meeting. In this meeting, a first approximation of the desired end product solution will be reached.

The result of this meeting is a detailed list of concrete functionalities, called Sprint Backlog (which is extracted from the Product Backlog). It consists of a set of tasks that fulfil the customer's requirements, each of which has to be completed in a cycle whose duration is set by the Scrum Master.

3. IMPLEMENTATION

The project is developed by carrying out tasks to be completed in constant periods of time, called Sprints. Sprints are the core of the SCRUM methodology. They correspond to the process of developing customer requirements divided into functional modules, so that at the end of each Sprint an incremental product is obtained. The time corresponding to each Sprint is established by the Scrum Master, but normally takes between 1 and 4 weeks, depending on the difficulty of the development.

This phase involves both the Scrum Master and the Development Team. The latter takes a leading role, as it is in charge of developing the functionalities described in the Product Backlog, while the Scrum Master takes a supporting role. However, in many cases, the Scrum Master can also be part of the Development Team.

One of the most representative activities of the SCRUM methodology is the Daily SCRUM. They consist of periodic (if possible, daily) meetings of the development team with the Scrum Master to constantly monitor the progress of the project. Four questions are discussed in these meetings, which are always a constant:

- What has been done since the previous meeting?
- What is going to be done until the next meeting?
- What is planned to be done after the next meeting?
- What problems have been encountered?

Each member of the development team should be involved in these meetings. They are designed to be of very short duration (less than 15 minutes), so that a global context of the updated status of the Sprint can be obtained on a daily basis. This facilitates the monitoring of the project and, therefore, decision making.

4. REVIEW AND RETROSPECTIVE

At the end of a Sprint, a new meeting is held, called Sprint Review. All project members (including the Product Owner) will be involved in this meeting, and the fulfilment of the objectives of the Sprint in question must be verified, in order to guarantee the delivery of the product to the end customer.

Every time a Sprint is finished, it is necessary to have a functional product. This functional product must be delivered to the customer so that he can interact with it, in such a way that he can check the progress of the project in an incremental way.

If all the objectives have been achieved and the product is delivered, this is when the Sprint Retrospective meeting is held. In this meeting, the results of the previous Sprint are analysed to reflect incidents, problems or improvements that may affect the next one. In this way, a new Sprint is started, which requires going back to the Product Backlog to extract customer needs that the current development of the project does not cover. This is repeated until the last Sprint is finished and, therefore, the project ends and the product is finished.

5. LAUNCHING

For the project to be considered completed, the client must receive both the complete product and the rest of the deliverables that were established at the beginning of the project. Once this phase is over, a Retrospective meeting is held again with all the members of the project, in such a way that all the relevant aspects of the development that may be useful for future projects are reflected.

KANBAN

The Kanban methodology, whose meaning in Japanese is "visual card", consists of the elaboration of a chart of pending, in process or finished works, in a very visual way, normally with glued cards, being this chart within reach of all the members of the team. It is a work method that requires constant updating of the same, to have under control the state of progress of the project. Thanks to its application, a greater simplification of planning and the allocation of responsibilities is achieved by means of the board, which can also represent work flows.

The main tool used for project monitoring is a Kanban board. This board consists of a variable number of columns (usually between 3 and 5), through which the progress of the planned tasks during a Sprint can be observed. Each task is separated into an independent piece of paper that goes through at least three states (corresponding to the columns of the board, Fig 5): pending, in progress and finished. This speeds up the process of understanding the Sprint that is being worked on, and also promotes transparency, in such a way that each member of the team can know the progress status of the tasks of the rest of the team.

The success of a Sprint depends on the entire development team. The aim is for everyone to have tasks assigned to them, for which they will be responsible. The objective is to guarantee the fulfilment of all the requirements of the Sprint within the defined timeframe.

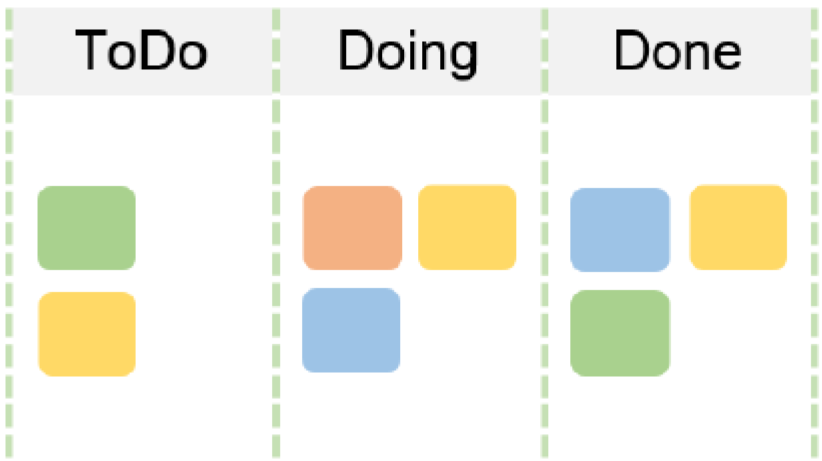

Figure 14. Simplified Kanban. Source: (Digité, 2016)

LEAN DEVELOPMENT

LEAN Manufacturing is a production system based on the elimination of all unnecessary resources in a process, minimising the amount of waste. It is an operational strategy of excellence created in the multinational automotive company Toyota, and its ideas have spread throughout the industrial sector worldwide.

The principles of LEAN Manufacturing are so clear that they can be reformulated to be applied to software development, giving rise to a software methodology known as LEAN Development. With its implementation, the aim is to optimise the development cycle from the first customer request to the delivery of the product and to achieve substantial improvements in the execution of the project. LEAN Development represents a highly effective software development process that, despite starting from an ideal basis, is entirely practical.

The ideas of the LEAN methodology, as applied to software development, lead to the pursuit of the following objectives:

- Focus on value delivery and quality improvement. The strength of value creation lies in reducing the amount of unnecessary resources.
- Improved decision making based on LEAN principles. This objective goes hand in hand with an essential term in this methodology: Just in Time. The best decisions have to be taken at the most important moments, optimising development and mitigating risks.

- Increased productivity, through the elimination of waste linked to software development. This will improve delivery times and develop quality products from the outset.

The basis of the LEAN methodology is to identify the waste that is generated during the development of a project, focusing on attitudes and beliefs considered acceptable, which in reality consume unnecessary resources.

LEAN principles

In order to use agile methodologies in software development, it is necessary to have an advanced knowledge of the more technical disciplines. Without this prior knowledge, the principles of methodologies such as LEAN Development are much less effective for the optimal development of projects. LEAN Development establishes the following principles:

1. Eliminate Waste

Waste represents everything that does not add value for the end user. They are all those actions that imply a bad consumption of the development team's resources (including time), such as developing unnecessarily complex solutions, redoing the same work several times, adding functionalities that the customer has not required...

All these actions do not add value to the user, therefore they are waste and need to be eliminated.

2. Amplify Learning

The development process itself is, in itself, a continuous learning process. The ideas acquired can be captured in the code or in simple text files, making it unnecessary to create documents that, in the medium to long term, may become useless.

The development process should be carried out in short cycles with frequent meetings, which will also favour the learning that is pursued and will serve to identify the needs of the client and the team.

3. Decide as late as possible

During the development of a project there are many critical decisions to be made.

4. Deliver as fast as possible

"First come, first served" is a maxim that is very representative of the current paradigm. Nowadays, the feedback received throughout the development process from the user is continuous and agile, so it is necessary to be active and deliver the product as fast as possible to satisfy the customer/user, as well as to keep a distance from the competition (if any).

5. Empower the team

A team should not be seen as a "set of resources" that are associated with a service. It should not be valued in number of hours or in economic cost. Ideally, the development team should assume its own management, have manageable and realistic tasks, and a direct contact with the client.

6. Build integrity in

The project, both client-facing and user-facing, must offer a robust image. Integrity is achieved by combining flexibility with a product that is maintainable in the long term, carrying out continuous iterations in short cycles, in order to improve functionalities based on user feedback.

7. See the whole

Most of today's projects are highly complex. To manage them correctly it is necessary to divide and decompose them into smaller tasks. It is necessary to reduce the size of the team in order to involve all parties. Projects can even be in the hands of several teams simultaneously.

3 METHODOLOGIES COMPARISON

As discussed in the previous topic one methodology described by the PMI (*A Guide to the Fundamentals of Project Management (PMBOK Guide), Sixth Edition*, 2017) is: “A methodology is a system of practices, techniques, procedures and rules used by those working in a discipline”. (Michael DePrisco, 2021)

But according to (Aston, 2021) a methodology must be rooted in something more fundamental so it determines that this definition should include themes. (Aston, 2021)
It therefore determines that methodologies should apply different principles, themes, frameworks, processes and standards to help structure the way we deliver projects. Following this description is the following classification:

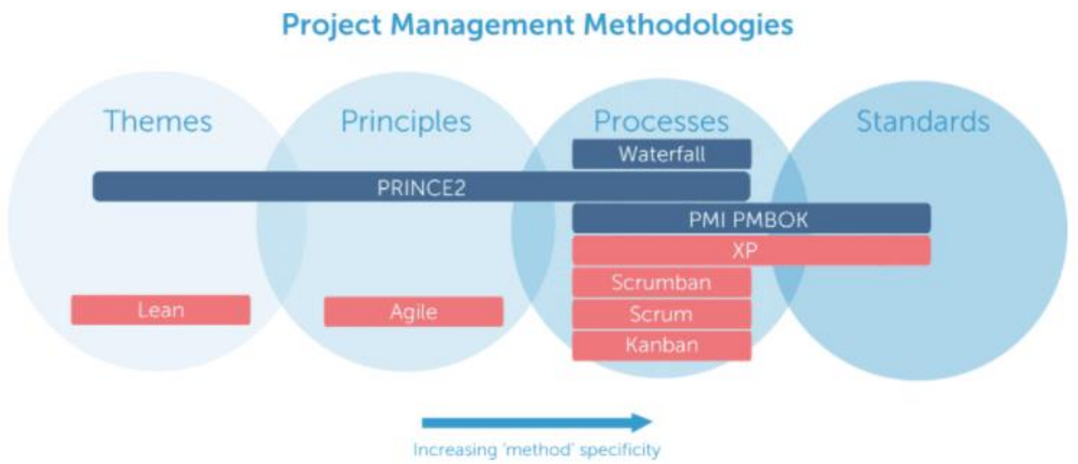

Figure 15. Project Management Methodologies. Source: (Aston, 2021)

In the graph in blue, we find the more traditional methodologies and in pink the AGILE techniques. Within the traditional methodologies, PRINCE2 methodology defines a complete methodology with themes, principles, and processes and PMBOK describes standards with some process. In the AGILE methodologies, XP, like PMBOK describes standards and some process while Scrum, Kanban and Scrumban define processes, Agile defines principles and Lean defines themes.

From this point on, the chapter will be organised as follows: first we will describe the situations in which the methodologies described in chapter 2 are and are not used; then we will focus on determining what the differences are between these practices and others; and finally the conclusion will be presented.

3.1 WHEN THE METHODOLOGIES SHOULD, OR SHOULD NOT, BE USED

In the previous chapter, methodologies have been presented, but when is it recommended to use them and for what kind of projects, and conversely, when is it not recommended to use them?

This section describes first the traditional methodologies and then the agile methodologies.

3.1.1 Traditional Methodologies

According to (Azanha et al., 2017) traditional project Management Methodologies do not do not fully meet the requirements of flexibility to absorb changes in the project. Furthermore, traditional project managements are not compatible with the complexity and dynamic change of software (Augustine et al., 2005). Following this idea, (Chin, 2004) declared that traditional methods have significant limitations in situations where innovation is high and teams are small (Chin, 2004).

- **WATERFALL**

It can be a useful and predictable approach if the requirements are fixed, well documented and clear, the technology is understood and mature, and the project is short. (Aston, 2021). Following on from this idea, (Monday, 2019) established that this methodology is ideal as long as the planning, scope and requirements are extremely clear and the outcome with this method will be successful and predictable.

Moreover, in order to the objective and requirements to remain the same, stakeholders must know exactly what it is or what they want. So that the project is consistent and predictable. On the other hand, this methodology is very useful if the industry in which the project is carried out is regulated and requires extensive project tracking and documentation. (Team Work, 2021)

On the other hand, as it is such a rigid methodology, and not very adaptable to any change, it is not advisable to use it if the objectives and requirements are not well defined and the project may change.
Following this line, it is also not recommended if continuous testing must be carried out, adapting to the client's requests, and making deliveries during the execution of the project.

Recommended	Not Recommended
Fixed requirements and targets	Undefined and variable requirements and objectives
Predictable	Project not predictable
Interested parties with clear ideas	Stakeholders with diffuse ideas
Sector with regulated measures	Sector with no documentation requirements
No project deliveries to the customer required	Proof of execution must be sent to the client
Highly repetitive projects: construction and manufacturing of the same product	Highly variable projects

Table 6. Waterfall requirements. Source: Own made (Azanha et al., 2017; Aston, 2021; Monday, 2019; Team Work, 2021)

- ## PRINCE2:

It is a cascading project management methodology that includes principles, themes and processes. (Aston, 2021). It is a very interesting structure for executing large and predictable projects that determines what will be delivered, ensures a feasible approach and defines in detail the project parts, roles and responsibilities. It is designed for large-scale IT projects (Aston, 2021). Following this line of thought, (Monday, 2019) also advocates the use of this methodology in large, well-defined projects.

On the other hand, like waterfall, it is not recommended if the project is small, as it can be a very time-consuming methodology to implement. Moreover, this methodology does not focus on teamwork (Monday, 2019). Finally, as it is a traditional methodology, its use is not recommended in very flexible projects with a high volume of changes.

Recommended	Not Recommended
Fixed requirements and objectives	Undefined and variable requirements and objectives
Large, well-defined projects. Large scale IT projects	Small and ill-defined projects
Predictable, no changes	Project not predictable
No emphasis on teamwork	Importance of teamwork

Table 7. PRINCE2 requirements. Source: Own made (Azanha et al., 2017; Aston, 2021; Monday, 2019; Team Work, 2021)

- **PMBOK**

As mentioned above, it is not a methodology, but a set of standards that determine the 5 steps to carry out a project. Its use is recommended for managing large-scale departments, companies that want all the departments or companies in the group to work in a standardised way. It is also applicable to smaller projects with high standardisation (Team Work, 2021)

On the other hand, this methodology is not recommended for small companies that work with projects with a high volume of changes at a high pace and it is not recommended if it is necessary to map, verify, the execution of the project in a way that changes the scope of the project.

Recommended	Not Recommended
Fixed requirements and objectives	Undefined and variable requirements and objectives
Large-scale projects	Small and ill-defined projects
Predictable, unchanging	High volume of changes
No mapping required	Need for mapping

Table 8. PMBOK requirements. Source: Own made (Azanha et al., 2017; Aston, 2021; Monday, 2019; Team Work, 2021)

3.1.2 Agile Methodologies

However, Agile itself is not a methodology or process that can be used. Agile is the global term used for its implementations, such as Scrum, XP, Kanban, Scrumban, etc.

It is characterised by emphasising adaptability in the face of changes in situations, promoting adequate communication and continuous improvement between the work team and between the team and the client. They are excellent methodologies for use in dynamic environments, with the possibility of changing the requirements during the execution of the project., dynamic environments that have a business environment influenced by constant changes. (Azanha et al., 2017). Following this idea, this methodologies are usually conducted under uncertainties in turbulent environments, characterized by complex projects, unpredictable activities and changes, scenarios where the traditional approaches have limitations. (Chin, 2004). Other authors corroborate that the agile approach is best suited for dynamic environments that have a business environment influenced by constant changes. (Boehm, 2004).

On the other hand, it is important to mention that agile methodologies abandon planning, reporting and scheduling in favour of flexibility and communication. (Azanha et al., 2017). So that, agile methodologies are noy suggested as the best universal practices (Highsmith, 2004).

Therefore, agile methodologies are interesting to use in dynamic, changing projects, where the solution at the beginning of the project is not known in its entirety since it can be adapted as the project is executed. Projects that need to work fast and where rapid progress and development is more important than a perfect result. For instance, software project. Nevertheless, However, it has been proven that these methodologies are not only applicable to software development projects.(Conforto et al., 2014) and that they can be used in projects such as the following image:

#	APM Management Practices	References (cited in the literature)
1	Use of the "product vision" concept	Highsmith (2004); Augustine (2005)
2	Use of simple project plan communication tools and processes	Highsmith (2004); Cohn (2005); Chin (2004)
3	Use of iterative planning	Eisenhardt & Tabrizi (1995); Boehm & Turner (2004); Highsmith (2004); Schwaber (2004); Augustine (2005); Cohn (2005)
4	Developing activities using self-managed and self-directed teams in the project plan	Takeuchi & Nonaka (1986); Boehm & Turner (2004); Highsmith (2004); Augustine (2005); Vázquez-Bustello, Avella, & Fernández (2007)
5	Use of self-managed and self-directed teams in the project plan monitoring and updating activities	Takeuchi & Nonaka (1986); Boehm & Turner (2004); Highsmith (2004); Vázquez-Bustello, Avella, & Fernández (2007)
6	Frequently apply project plan monitoring and updating processes	Eisenhardt & Tabrizi (1995); Andersen (1996); Boehm & Turner (2004); Highsmith (2004); Augustine (2005); Cohn (2005)

Figure 16. Management practices related to the agile project management approach. Source: (Conforto et al., 2014)

However, it is not advisable to use these methodologies if the project requires a high degree of documentation and reporting. If the deliverables have exacted and immovable deadlines and must be predictable and clear from the beginning. Finally, if the project to be developed does not need the client's opinion, the ideas are clear and fixed and cannot be varied during the execution, these are not the best methodologies to apply. (Team Work, 2021).

Although as methodologies belonging to this large group they share many similarities, the Agile methodologies studied in the previous chapter are presented below to determine in more detail when it is advisable and when it is not advisable to use them.

- **SCRUM**

This methodology was originally designed for software development and R&D, although it has also been applied to other types of projects.

It is an ideal methodology for creative projects, where changing something does not imply putting the whole project at risk. (Aston, 2021). Therefore, its use is recommended in dynamic projects, where continuous improvement is desired. It is normally used in projects with small groups of up to 10 people, although it is true and although it is not recommended, there are companies that have used it for large projects and have been successful (Monday, 2019).

As an agile methodology, it dispenses with a lot of the documentation phase, therefore, Scrum is recommended in projects where this is not a regulatory requirement of the client or the company. In addition, it focuses on fast deliveries and a lot of control over the project, involving the client at all times in decision making, therefore, it is essential to be able to count on the client's feedback.

Finally, it is an ideal methodology to implement in changing environments, where the objectives do not have to be defined from the beginning and where changes can be made in the middle of the project. (Monday, 2019; Team Work, 2021; Azanha et al., 2017; Aston, 2021; Augustine et al., 2005; Beck et al., 2001; Chin, 2004; Highsmith, 2004; J. Highsmith & A. Cockburn, 2001; Matovic, 2020).

Recommended	Not Recommended
Undefined and variable requirements and objectives	Fixed requirements and targets
Unpredictable, changing environments	Predictable
Dynamic and creative projects	Interested parts with clear ideas
Small groups of up to 10 people	Big groups, more than 10 people
Not regulatory required	Highly repetitive projects: construction and manufacturing of the same product
Client involved	No project deliveries to the customer required

Table 9. SCRUM requirements. Source: (Aston, 2021; Azanha et al., 2017; Monday, 2019; Team Work, 2021)

- **KANBAN**

Ideal methodology for operational or maintenance environments where priorities tend to vary frequently and require consistent performance.

This methodology was developed specifically for software development, although it is applicable to virtually any predictable process. (Monday, 2019). It is highly recommended to apply if you want to have a global vision of the execution of the project, its process and the updates that are being carried out. Therefore, it is ideal for working with continuous improvement. Although we will later study the differences between the methodologies, it is worth highlighting that one of the differences with SCRUM is that KANBAN does not require daily meetings.

On the other hand, if the process to be carried out is very complex or consists of many stages, it is not advisable to use this methodology as it will lead to a great waste of time.

Recommended	Not Recommended
Operational or maintenance environments	Fixed requirements and targets
Need of having a global vision of the execution project	Complex projects
Predictable process	Non defined process
Continuous improvement	No need to improve
Dynamic and creative projects	Sector with regulated measures

Table 10. KANBAN requirements. Source: (Aston, 2021; Azanha et al., 2017; Monday, 2019; Team Work, 2021)

- ## LEAN

It is a methodology that is easy to implement in manufacturing or production environments of a physical product such as a car. In addition, this methodology is also widely used in project delivery processes as it reduces unnecessary data, increases the value of the project and optimises it. (Aston, 2021). Continuing with this idea, (Team Work, 2021) corroborates that this methodology is characterised by improving and adding value to the project for the client as well as reducing costs. (Monday, 2019) adds that this methodology increases work efficiency, eliminates waste of obsolete stock and improves the quality of customer relations and communication. However, it is not recommended for use in teams working digitally.

- ## XP

As an Agile methodology, XP has very similar characteristics of use to those mentioned above. However, we can highlight that it differs from other methodologies such as Scrum in that XP establishes rules related to design, coding and testing specific to development projects.

In addition, it has been found to be a very useful methodology for fostering teamwork and collaboration among project members, especially for small teams.

- ## OTHER METHODOLOGIES

The methodologies described above are the most widely used by companies but it is true that there are many other methodologies including PRiSM, Critical Path, PERT, Crystal Method in which project processes are given low priority emphasising the skills, communication and interaction of the team or Adaptive Framework (APF or APM), where the objective of this methodology is to be adaptable to change, in fact, it was designed taking into account the inevitability of change. Therefore, teams must be prepared to anticipate risks and constantly re-evaluate results and decisions. The scope of the project is variable, but the time and cost are constant, making it possible to adjust the scope of the project during execution to get the maximum business value from the project. This methodology requires high communication between all stakeholders. Finally, this methodology is recommended if the final objectives are known but if you need predictability and do not have the necessary resources to deal with scope variations, rework or misuse of time, it is not advisable to use this methodology.

ABSTRACT

The following image shows the classification according to the different methodologies that have been explained, depending on whether they are stable projects or projects that need to be carried out quickly and whether they are fixed or dynamic projects:

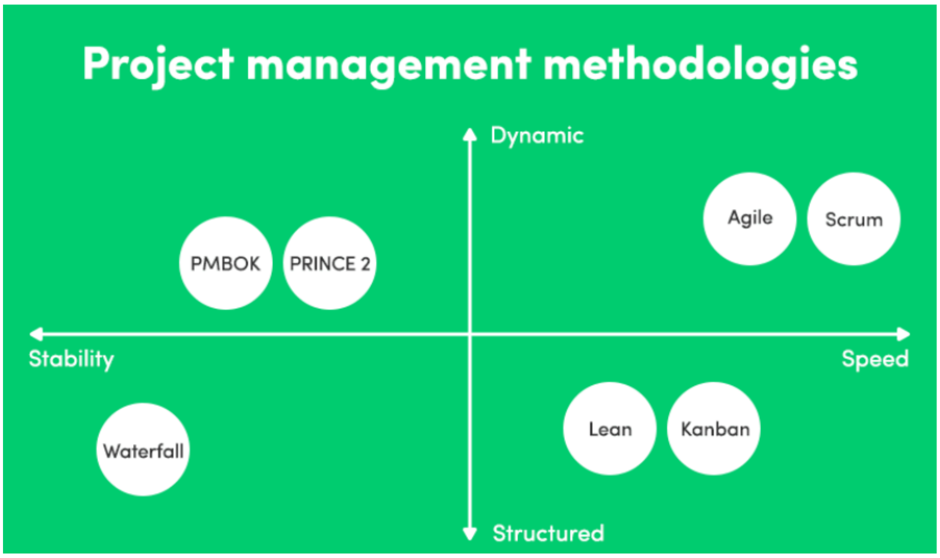

Figure 17. Comparison between the methodologies. Source: (Monday, 2019)

3.2 COMPARISON BETWEEN METHODOLOGIES

So far we have studied the main characteristics and elements of the methodologies in chapter two and when it is advisable to use each methodology. Once we have this knowledge, we only have to compare the different methodologies in order to have a better knowledge when choosing the methodologies that best suit our project.

In this section we begin by comparing the two main groups that have been explained, traditional and agile, and then we compare the methodologies that make up each group.

3.2.1 AGILE VS TRADITIONAL

We have studied the recommendations for using or disliking both agile methodologies and traditional methodologies. Next, we are going to compare the characteristics of all the methodologies studied to mark the differences and similarities that exist between them.

Shenhar and Dvir (Shenhar & Dvir, 2007) The following comparison between the above-mentioned methodologies was made, highlighting the main characteristics that differentiate them:

Approach	Traditional	Agile
Project objectives	Focus on completing the project on time, cost and quality requirements	Focus on business results, achieve multiple success criteria
Project plan	A collection of activities that are performed as planned to meet the triple constraint (time, cost and quality)	An organization and the process to achieve the expected goals and results for the business
Planning	Held once early in the project	Performed at the beginning and held whenever necessary
Managerial approach	Rigid, focusing on the initial plan	Flexible, adaptive variable
Work/execution	Predictable, measurable, linear, simple	Unpredictable and not measurable, non-linear, complex
Organizational influence	Minimum, impartial, from the project kick-off	Affect the project throughout its execution
Project control	Identify deviations from the original plan and correct the work to follow the plan	Identify changes in the environment and adjust the plan accordingly
Methodology application	Generic and equal application across all projects	Process adaptation depending on the project type
Management style	A model serves all project types	Adaptive approach, a single model does not attend all project types

Table 11. Differences between agile and traditional project management approaches. Source: (Shenhar & Dvir, 2007)

	AGILE	TRADITIONAL
PROJECTS OF OBJECTIVES	Focus on business results and achieve multiple success criteria	Focus on completing the projects on time, cost, and quality requirements
PROJECT PLAN	A collection of activities that are performed as planned	An organisation in the process to achieve their expected goals
DEVELOPMENT MODEL	Evolutionary delivery	Life cycle. Held almost early at the beginning
METHODOLOGY APPLICATION	Process adaptation depending on the projects type	Generic and equal application across all projects
MANAGERIAL APPROACH	Flexible adaptive variable	Rigid, focusing on the initial plan
WORK EXECUTION	Unpredictable, not measurable, non-linear and complex	Predictable, measurable, linear, and simple
ORGANISATIONAL STRUCTURE	Iterative	Linear
SCALE OF PROJECTS	Small and medium	Great
REQUIREMENTS	Dynamic	Well defined before starting
CUSTOMER INVOLVEMENT	High, involved from the moment work is started until end	Low, involved at the beginning and until implementation start
ESCALATION MANAGEMENT	The team solve the problem	Problem is scale to project managers
MODEL PREFERENCES	Adaptation	Anticipation
PRODUCT OR PROCESS	Less focus on formal, directive processes	More process-focused than product-focused
PLANNING	Sprint planning, not all planned	Everything is planned in great detail
EFFORT ESTIMATION	Scrum master facilitates tasks and team does the estimating	Project manager estimates and gets approval from project owner
REVIEWS AND APPROVALS	Reviews after each iteration	Constant reviews and approvals just by project leaders
MANAGEMENT STYLE	Adaptive approach, one model does not attend all project types	One model serves all project types

Table 12. Traditional vs Agile project Management. Source: Own made. (Azanha et al., 2017; Haworth, 2021; Layton et al., 2020; Matovic, 2020; Shaydulin & Sybrandt, 2017; Špundak, 2014)

In addition, there is also a comparison between traditional and agile methodologies dedicated to software development shown in the table below:

Categories	Traditional	Agile
Development model	Traditional	Iterative
Focus	Process	People
Management	Control	Facilitate
Customer involvement	During requirements definition and on the delivery phase	Always involved
Developers	They work individually within the teams	Collaborative or in pairs
Technology	Any	Object oriented mostly
Product characteristics	All included	Most important first
Tests	At the end of development cycle	Iterative
Documentation	Complete	Only when necessary

Source: Adapted from Hoda *et al.* (2010)

Table 13. Differences between agile and traditional software project management. Source: (Hoda et al., 2010)

The following image shows a very visual representation of the difference in development between traditional projects, focusing on waterfall methodology, and agile projects.

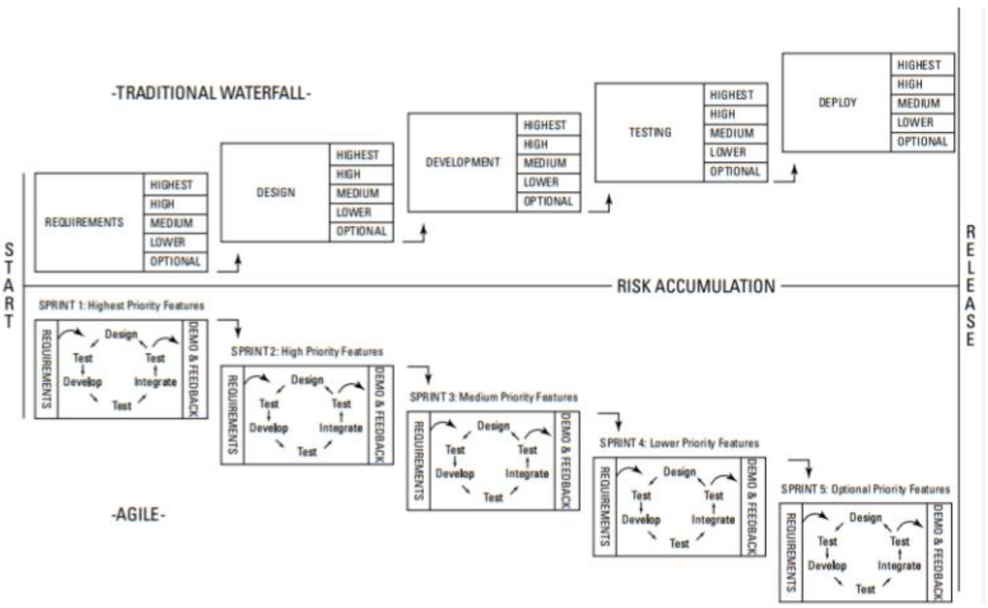

Figure 18. Agile vs Waterfall. Source: (Layton et al., 2020)

We have just compared the different characteristics that encompass traditional and agile methodologies, but the following is a study conducted by (Chin, 2004) which classifies when and for which projects different methodologies should be used.

According to (Chin, 2004) and as shown in the figure below, the pure and unique application of agile methodologies is best suited to:

- New technology or product development projects with high levels of certainty, creativity, dynamism, and high team commitment.
- Projects developed in a single business unit in an organization where the customer is the department itself, for example, the department of research and development.

On the other hand, the pure application of traditional techniques will fit better in projects with a high level of certainty, where the unknown is low and predictable, such as multiple organisations and operational projects.

Finally, this author proposes to use a hybrid methodology, which would be to combine agile and traditional methodologies and tools in new product and process development projects and also in projects where there is a single organisation, but with many business units involved. The following image shows a summary of what has been described so far.

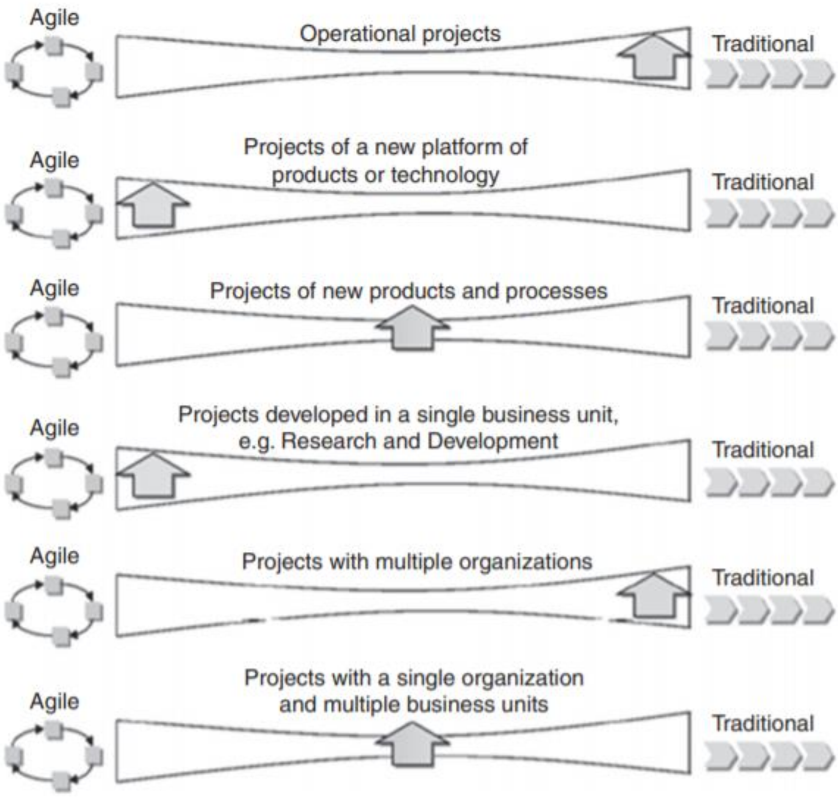

Figure 19. Application of agile and traditional management methodologies.

Source: (Azanha et al., 2017)

3.2.2 TRADITIONAL: WATERFALL VS PMBOK

Although the two methodologies are closely related and are often linked, they are not the same.
PMBOK is essentially a project management guide where it categorises best practices for project management. On the other hand, Waterfall is a basic development guideline while PMBOK provides a large number of techniques to better manage that development. Which, as mentioned at the beginning, means that they are closely related since PMBOK covers many essential aspects to properly manage a Waterfall project (Morton, 2011).

3.2.3 AGILE

- **SCRUM VS KANBAN**

The fundamental difference between these two methodologies focuses on what they demand from the project, i.e. how strict the project needs to be.

Therefore, it can be determined that the differences from the Kanban point of view:

- Kanban allows teams and their members to organise themselves more freely whereas Scrum is stricter with the organisation.
- In Kanban the establishment of roles in a team is not a requirement, however it is one of the key points that the SCRUM methodology establishes.
- The meetings in Kanban are not restricted by deadlines or iterations, in SCRUM the sprint conditions the establishment of the meetings.
- The Kanban board is continuously updated and stories can be added at any time if they are applicable to the current workflow.
- Any member or team can be the owner of the board.
- No estimates are needed for tasks

(Andrei et al., 2019, pp. 128–130)

On the other hand, there are a number of similarities between the methodologies to consider:

- Both methodologies need to be tested before a team can decide which approach to adopt
- Both focus on rapid delivery of functionality
- Both will discuss frequently with the customer to get their feedback as early as possible.

(Andrei et al., 2019, pp. 129–130)

As both methodologies have a number of very useful and beneficial behaviours, bringing them together as a hybrid methodology has resulted in SCRUMBAN.

SCRUMBAN

This is a hybrid methodology, meaning a mixture of 2 known methodologies in which the appropriate characteristics needed for the execution of the project are taken advantage of. Although this methodology has not been presented in the previous chapter, being one of the many applicable hybrid methodologies, it is interesting and applicable to many projects.

This hybrid methodology helps to improve the effectiveness of Sprint engagement. However, it also introduces the WIP boundary as a mechanism to catalyse incremental change. The WIP boundary avoids the need to commit to driving change, reduces any dysfunctional reliance on effort and improves overall systems thinking when considering potential improvements. (Julio Roche, 2019)

- ## XP VS SCRUM

These two agile methodologies are closely related to each other and therefore the differences between them are minimal:

	XP	SCRUM
ITERATION TIME	1 or 2 weeks.	2 weeks until one month.
CHANGING ITERATIONS	It accepts changes in its iterations as long as a particular requirement has not been started.	Meeting items are defined in the backlog and no changes can be made until the end of the backlog.
ITERATION ORDER	Requirements are prioritised by the customer (product owner in SCRUM) and the team must follow it.	The product owner prioritises the product backlog but the team determines the order.
BEST PRACTICES	Process adaptation depending on the projects type	Generic and equal application across all projects
SOFTWARE	The software needs to be validated all time, to extend that test are written prior to the actual software.	The validation of the software is completed at the end of each sprint, at Sprint Review.

Table 14. Comparison between XP ans SCRUM. Source: (Kniberg, 2007)

- ## SIMILARITIES BETWEEN

Table 4-2 Similarities Between Lean, Extreme Programming, and Scrum

Lean	*Extreme Programming*	*Scrum*
Engaging everyone	Entire team Collective ownership	Cross-functional development team
Optimizing the whole	Test-driven development Continuous integration	Product increment
Delivering fast	Small release	One- to four-week sprints

Figure 20. Similarities between Lean, XP and Scrum. Source: (Layton et al., 2020)

3.3 HYBRID METHODOLOGIES

So far we have described when the different methodologies should be used or not and have been compared between them, but in a moment we have written the hybrid methodologies since we have focused on deepening and knowing properly all the methodologies and their uses in order to choose the best methodology or combination of methodologies to apply in the next chapter to solve our project management problem.

Many articles state that there is no single project management methodology that covers all needs, hence the existence of hybrid methodologies. Following this line of thought *A case study of a Brazilian pharmaceutical company IT project* (Azanha et al., 2017) He determined that in order to select the right methodology it is very important to take into account the decision strategy and added that in many cases a single methodology will not be sufficient but that the combination of traditional and agile methodologies will not be enough can be customized and adapted to the requirements of each project. (Azanha et al., 2017).

In addition, the following image shows the other study in which the comparison and evaluation of very different agile methodologies determined that agile methodologies do not adapt well to large scale which could explain the existence of traditional waterfall approach (Shaydulin & Sybrandt, 2017).

		Methodology						
		Waterfall	AUP	Scrum	TDD	RAD	JAD	FDD
Quality Criteria	Requirements flexibility	No	Yes	Yes	Yes	Yes	Yes	No
	Requirements fulfillment guarantee	Yes	Yes	Yes	No [1]	Yes	No	Yes
	Cost estimation	Yes	Yes	Yes	No	Yes	No	Yes
	Cost estimates refinement	No	Yes	Yes	No	Yes	No	Yes
	Validation	Yes	Yes [2]	Yes [3]	Yes	Yes	Yes	Yes
	Quick validation	No	Yes [2]	Yes [3]	Yes	Yes	Yes	Yes
	Focus on customer	No	Yes [4]	Yes	No	Yes	Yes	No
	Understandability guarantee	Yes [5]	No	No	No	No	Yes [6]	No
	Technical debt control	Yes	No	No	Yes	No	No	No
Agility Criteria	Prioritizes added value	No	Yes	Yes	Yes	Yes	Yes	Yes
	Allows partial requirements	No	Yes	Yes	Yes	Yes	Yes	Yes
	Focuses on small teams	No	Yes [7]	Yes	Yes	Yes	Yes	Yes
	Develops minimal viable architecture	No	Yes	Yes	Yes	Yes	Yes	Yes
	Produces minimal documentation	No	Yes	Yes	Yes	Yes	No	Yes
	Relies heavily on customer feedback	No	Yes	Yes	No	Yes	Yes	No
	Susceptible to unforeseen risks	No	Yes	Yes	Yes	No	Yes	Yes

Figure 21. Result of the evaluation of different methodologies. Source: (Shaydulin & Sybrandt, 2017)

Furthermore, the same study, the result of which has been presented in the picture above, demonstrated that of all the methodologies compared, none adequately addressed all the important aspects of the software design process. This same article offered a hybrid implementation idea consisting of the following: using waterfall for project planning; Scrum for short-term goals and XP for software remediation.

Moreover, Vijayasarathy stated that more than 45% of software teams use a hybrid approach (Vijayasarathy & Butler, 2016). As can be seen in the following graphic:

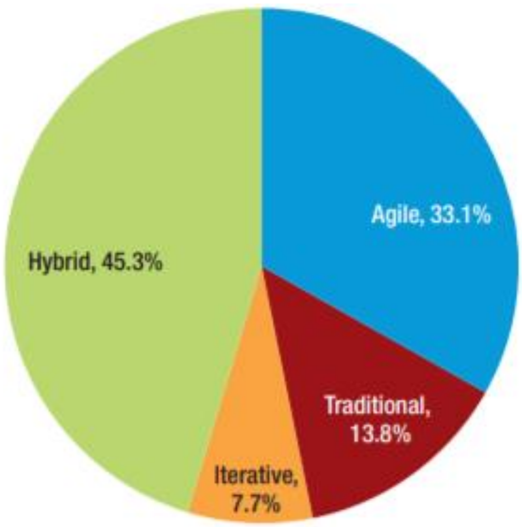

Figure 22. Methodologies used in projects. Source: (Vijayasarathy & Butler, 2016)

In addition, the same study made a comparison of the number of teams involved in a project and the methodologies that were most commonly used efficiently and effectively.

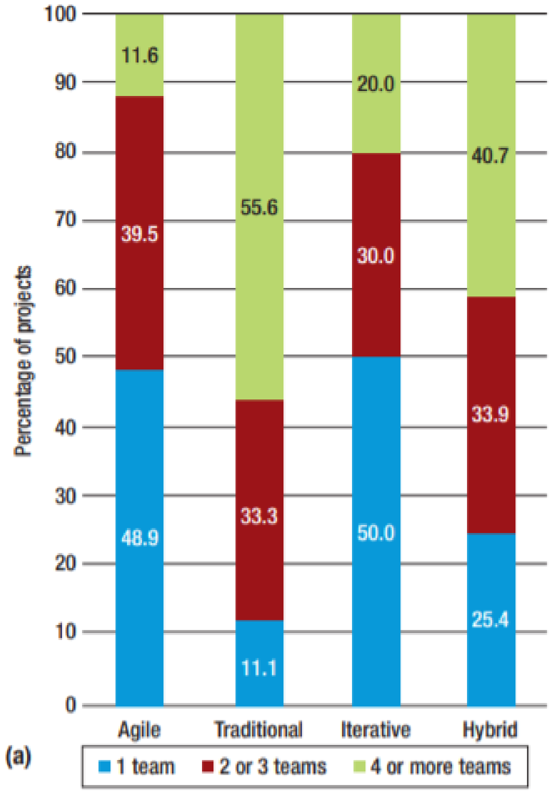

Figure 23. Number of teams and project management. Source: (Vijayasarathy & Butler, 2016)

4 BEER PROJECT 4.0

This chapter presents the beer production project at the University of Albstadt Sigmaringen.

4.1 PROJECT CONTEXT

The project consists of automating the brewing process by implementing a Smart Factory simulation. The main objective is to improve the quality of beer production and to be a leader in innovation. The aim is to improve process stability and product quality in the fermentation area.

The fermentation process is prone to quality fluctuations, the aim of the students is to optimise the process by eliminating deficits.

Below is a table with the deficits and the objectives to be achieved by automating and optimising the process.

Deficits	Improvements
Low process stability	High process stability
High quality fluctuations	Consistently high product quality
Uncontrollable quality	Automated control and documentation of the fermentation process
Lack of automation	
Reduction of benefits **-14.34% (~115 thousand €)**	Increase in profit potential **66,16% (~ 530 in thousands of euros €)**

Table 15. Beer production project. Deficits and Improvements. Source: Albstadt-Sigmaringen University.

As shown in the table, there would be a potential increase of 66.16% by eliminating 14.34% of the deficits and increasing capacity and quality by 51.82%.

4.1.1 PARTICIPANTS

The project is carried out by students of the University of Albstadt Sigmaringen from three different computer science degrees, resulting in three groups, each consisting of only students of the same degree and focusing on a specific programme.

Those in grade Business Informatic are focus on using SAP, those in grade Informatic Security are more focus on SPS and those in grade are focus on MQTT commmunication. The software they use is as follows:

SAP is a kind of ERP system enterprise which solves planning system. There are a lot of providers of ERP but SAP is the most well-known and important one because a lot of companies operate it. PLC (SPS) is a programmable logic control or control device. MQTT is a protocol used for communication between the ERP system and the SPS system. This team was the intermediate layer where they translate the messages which come from SPS into a message that SAP could understand.

4.1.2 PROJECT MANAGEMENT

In this section we will study what project management techniques have been used so far, then we will study the problems that have arisen in the past, and finally we will study the solutions and propose new forms of management focused on Industry 4.0 and virtual projects.

4.1.2.1 TOOLS USED SO FAR.

✓ *CANVAS*

This methodology is commonly used for the development of business models and has nine sections, which are as follows:

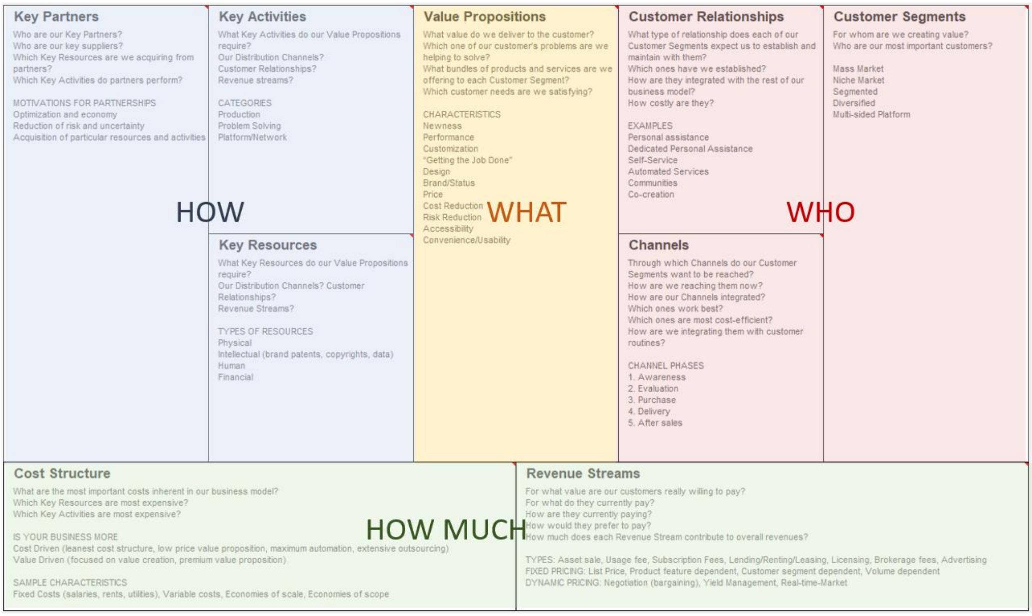

Figure 24. Canvas tool estructure.

However, a kind of CANVAS model has been used in this project, which provides a summary and the main features of the model that the students must take into account in order to implement the project:

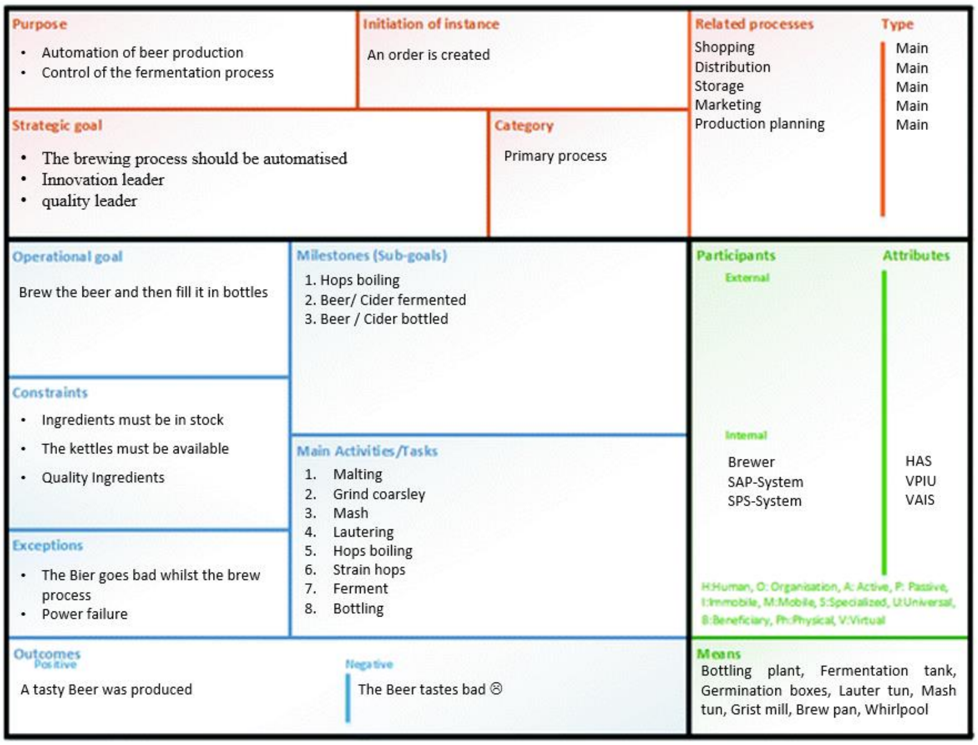

Figure 25. Version of Canvas used in the Beer production project. Source: Albstadt-Sigmaringen university

✓ *SEQUENCE DIAGRAM*

Sequence diagrams are intended to determine the interactions between the different objects and to describe the sequence and order of the objects.

✓ *GANTT DIAGRAM*

As already discussed in section X of chapter 3, the Gantt chart is a graphical project management tool whose purpose is to determine the time spent on a task or activity within a total time.

However, as some students have commented, the Gantt was not always adhered to as the project was not so much fixed, but evolving.

4.1.2.2 PROJECT MANAGEMENT CHALLENGES

Despite the tools used, there are several management problems in the project. In the previous year, the course consisted of around 12 students and three large groups. This year there are three students in total, divided into two groups. Please note that the content has been simplified due to the smaller number of students.

Before we start describing the problems, let us differentiate between the two groups. Last year's large group will henceforth be called Sample A and this year's small group will be called Sample B.
The variety in the group allows us to carry out a study of the situation in order to draw conclusions. In this section we present the situation studied in the previous year compared to this year.

SITUATION A

As mentioned above, a total of 12 students from three different branches of computer science participated in this project. Sample A is made up of three groups, each consisting only of students from the same branch.
One of the problems that could be observed was a problem of interpretation, as they belong to different branches of computer science, the computer languages of each group of students are different but the data of the groups are interrelated and therefore need each other. This leads to difficulties in the interpretation of data, loss of time and computer errors.

On the other hand, a communication problem was observed. Weekly meetings were held to share what each team was doing, what problems arose and what they were going to do until the next weekly meeting. These meetings were attended by the whole group of students, but only a few of them spoke, what was presented was not written down, each group presented their tasks and did not take into account other people's circumstances. The lack of communication resulted in lost time in implementation, tasks being duplicated or not carried out at all, and errors at the end of the project that were triggered by poor management at the beginning. All this resulted in a great loss of time, delays in the work and stress for the students on dates close to the delivery of the project.

SITUATION A		
Number of participants	Around 15	
Number of groups	3 groups: SAP, SPS, MQTT	
Project management tools used	-Gantt -Sequence diagrams -Kanban	
Participants in meetings	All the students	
Number of meetings	One weekly	
Problems	Communication	- Problems with the sequence of information flows. -Lack of communication between groups. -Lack of attention from learners. -Lack of consideration for the needs of others.
	Data interpretation	-Difficulty in understanding foreign languages. -Computer errors

Table 16. Situtation A project beer porduction. Source: selfmade.

SITUATION B

Sample B consists of only three students in total. Two of them belong to the SAP group and one of them to the SPS team. This year there is no MQTT team so the communication between SPS and SAP is done through online meetings.

The communication is done directly between the SPS and SAP devices using the MQTT programme, this is done with a broker where all the information is stored and where you can select the information you want to use. The management tools used are the same as the previous year, two weekly meetings are held in which the students present their progress, the weekly objective they set themselves and if they have any problems in the programming. Occasionally there is an additional meeting. This year, the communication problems of the previous year have not been observed.

SITUATION B	
Number of participants	3 students
Number of groups	2 groups: SAP, SPS
Project management tools used	-Gantt -Sequence diagram -Kanban
Participants in meetings	All students
Number of meetings	Twice a week
Problems	No problems observed

Table 17. Situation B project beer production. Source: self-made.

CONCLUSIONS OF THE SAMPLE COMPARISON

The comparison is shown below:

	SITUATION A	SITUATION B
Number of participants	Around 12	3 students
Number of groups	3 groups	2 groups
Project management tools used	-Gantt -Sequence diagram -Kanban	-Gantt -Sequence diagram -Kanban
Participants in meetings	All students	All students
Number of meetings	Once a week	Twice a week
Problems	Communication Data interpretation	No problems observed

Table 18. Comparison between Situation A and B. Source: self-made.

After analysing the groups, it can be concluded that having small groups in the meetings increases the communication and attention of the participants. In addition, it facilitates understanding, which results in time savings.

Therefore, from the study of the groups we can affirm that smaller groups improve communication. Applying this to a large group, we could think of establishing roles within the teams in sample A, so that meetings with other groups would be held in small groups.

SITUACION C: AGILE METHODOLOGY IMPLEMENTATION PROBLEM

In the implementation of this project, the agile SCRUM methodology was used for project management. The problem that arose was that as everything was divided into small work packages, the different groups blocked communication between them as they did not consider it important or necessary. So a communication flow problems arise.

4.1.2.3 PROJECT FEATURES

The characteristics of the project are presented below.

PROJECT CHARACTERISTICS

Number of teams	Between 2 and 3 teams
Size of teams	Between 1 until 6 members
Possibility of changes during execution	Yes
Development model	Evolutionary/Held almost early at the beginning
Managerial approach	Flexible adaptative variable/ rigid, focusing on the initial plan
Work	Unpredictable, not measurable, non-linear and complex
Reviews after each iteration	Yes
Planning	Not all is planned since de beginning
Customer involment	High
Requirements	Dynamic but also well-defined before starting
Documentation	Not as important

Table 19. Project characteristics. Source: Albstadt-Sigmaringen university.

4.2 METHODOLOGIES FOR THE MANAGEMENT OF 4.0 PROJECTS APPLICABLE TO THIS PROJECT.

Having analysed the problems and determined a possible solution, we look at the current methodologies that could be applied to projects oriented towards Smart factories and more specifically to this project.

Before determining which could be the possible solutions and methodologies to follow for this project, we must consider what are the main characteristics of 4.0 projects and how to manage them.

4.2.1 CHARACTERISTICS OF THE INDUSTRIAL REVOLUTION PROJECTS

Although in the article, Project management methodologies in the fourth industrial revolution (Pajares et al., 2017) does not determine any methodology to be followed for this type of Industry 4.0 oriented projects, it establishes the characteristics that the projects of the 4th industrial revolution will have.

- **PRESSURE ON PROJECT DEVELOPMENT TIMES**

Determines that in recent decades product life cycles have shortened drastically, so it is now necessary to take into account that sometimes being first to market is more important than reducing development costs, so time will be one of the most important variables in project management (Pajares et al., 2017, pp. 130–131).

Due to the need for speed in the development of projects, it would be more advisable to apply an agile methodology as they are focused on developing the project more quickly.

- **BUSINESS MODEL ORIENTATION**

It states that sometimes, the physical outcome of the project will not be known at the beginning of the project (uncertainty in the objectives) and therefore the "plan" and deliverables will be revealed during the execution of the project depending on the outcome of the project activities. Furthermore according to this article: The project describes a path, which unfolds during the time of project execution time, and is not predictable before the project starts and determines that projects at the current technology frontier, will need to adopt a trial and error management type of management. (Pajares et al., 2017, p. 131).

Again, it orients project management towards an agile methodology.

- **INTER-RELATION BETWEEN FIRMS: COOPERATING IN A NETWORK**

In terms of our project, instead of being an interrelationship between firms, we could establish that it would be an interrelationship between groups. In any case, this article determines that the project management of the technological revolution will work in new innovative ecosystems. (Pajares et al., 2017, pp. 131–133).

Although they do not literally determine a methodology, by analysing this article with the literature studied, I have determined that the methodology that best fits in all cases for 4.0 projects is agile.

SUMARISE PROJECT 4.0 CHARACTERISTICS

CARATERISTIC	**RESULT**	**AGILE OR TRADITIONAL**
Pressure on project development times	▪ Time is a very important variable ▪ Need to finish the project quickly	*AGILE*
Business model orientation	▪ Physical outcome not known until the end of the project ▪ Unpredictable ▪ Trial and error management	*AGILE*
Project of the technological revolution are complex in nature	▪ Innovation	*AGILE*

Table 20. Sumarise project 4.0 characteristics. Source: Selfmade following (Pajares et al., 2017).

4.2.2 PROJECT OF THE TECHNOLOGICAL REVOLUTION ARE COMPLEX IN NATURE

Finally, it should be noted that different project types require different managerial approaches.

Therefore, establishing a single methodology would not be appropriate due to the complexity of the project.

4.3 PROBLEM SOLUTION

4.3.1 JUSTIFICATION OF THE METHODOLOGY

With data obtained from:

- ✓ Literature reviewed in chapter 2 and comparison of methodologies, when it is advisable to use one or the other in chapter 3.
- ✓ Data and comparison of the problems of the situation in previous years and this year
- ✓ Characteristics of the project under study.
- ✓ Review of the characteristics of Industry 4.0 projects.

We proceed to determine the most recommended methodologies to find possible solutions to project management problems.

- ✓ **Literature reviewed in chapter 2 and comparison of methodologies, when it is advisable to use one or the other in chapter 3.**

  According to the literature reviewed, for projects consisting of two or three teams, the most commonly used methodology is agile, followed by hybrid methodologies.

  If the projects are formed by 4 or more teams, the most used methodology is traditional, followed by hybrid.

  On the other hand, it is established that there is no methodology that completely fulfils all the requirements of the project. Therefore, it also leads to the use of hybrid methodologies.

CARATERISTIC	*AGILE OR TRADITIONAL*
Proyect with 2 o 3 teams	*AGILE then HYBRID*
Proyects with 4 teams or more	*TRADITIONAL then HYBRID*
Project of the technological revolution are complex in nature	*AGILE*

Table 21. Methodologies recommended from the literature. Source: selfmade following the literature reviewed.

✓ **Data and comparison of the problems of previous years and this year's situation.**

Following the comparison between situation A with situation B it can be seen that the problem arises when a meeting is attended by too many people, all of them without a defined responsibility.

In the situation B, the meetings were small in number and there were no communication problems.

In conclusion a small group meeting increase communication and attention from the participants.

✓ **Characteristics of the project under study.**

In line with the characteristics of the project under study in the Table 19 and Table 19. Project characteristics. Source: Albstadt-Sigmaringen university.comparing it with Traditional vs Agile project Management. Source: Own made. (Azanha et al., 2017; Haworth, 2021; Layton et al., 2020; Matovic, 2020; Shaydulin & Sybrandt, 2017; Špundak, 2014)Table 12 to determine which methodology to use, the following table is obtained:

PROJECT CHARACTERISTICS

VARIABLES	*CHARACTERISTICS*	*METHODOLOGY*	
Number of teams	Between 2 and 3 teams	AGILE	
Size of teams	Between 1 until 6 members	-	
Possibility of changes during the execution	Yes	AGILE	
Development model*	Evolutionary/Held almost early at the beginning	AGILE	TRADITIONAL
Managerial approach	Flexible adaptative variable/ rigid, focusing on the initial plan	AGILE	TRADITIONAL
Work	Unpredictable, not measurable, non-linear and complex	AGILE	
Reviews after each iteration	Yes	AGILE	
Planning	Not all is planned since de beginning	AGILE	
Customer involment	High	AGILE	
Requirements*	Dynamic but also well-defined before starting	AGILE	TRADITIONAL
Documentation	Not as important	AGILE	

Table 22. Methodologies to be used according to the characteristics if the project. Source: selfmade following the litarature.

Therefore, as can be seen from studying the characteristics of the project and following what has been studied, the most recommendable methodology to apply would be AGILE.

✓ **A review of the characteristics of Industry 4.0 projects**

As observed in the Table 20, although the articles determine that there is no established methodology that can be applied in its entirety in Industry 4.0 oriented projects, AGILE methodologies are the most recommended.

SUMARISE PROJECT 4.0 CHARACTERISTICS

CARATERISTIC	RESULT	AGILE OR TRADITIONAL
Pressure on project development times	▪ Time is a very important variable ▪ Need to finish the project quickly	*AGILE*
Business model orientation	▪ Physical outcome not known until the end of the project ▪ Unpredictable ▪ Trial and error management	*AGILE*
Project of the technological revolution are complex in nature	▪ Innovation	*AGILE*

Table 23. Sumarise project 4.0 characteristics. Source: Selfmade.

4.3.2 CONCLUSION OF THE METHODOLOGY TO BE USED

The methodologies to be implemented for the solution of communication and information flow problems are AGILE methodologies.

The four cases studied focus more on the use of agile methodologies.

On the other hand, and as has also been mentioned in previous topics, the following circumstances occur:

- ✓ There is no focused methodology for projects in a Smart factory, industry.
- ✓ There is no methodology that meets all the necessary requirements for this type of project.

Therefore, in line with the previous point, hybrid methodologies are mainly recommended and used.

From this point on, we focus the study on finding solutions to the problems with several agile methodologies, i.e. **<u>we will use a hybrid methodology based on the different agile methodologies.</u>**

- **POSSIBLE SOLUTION FOR THE COMMUNICATION AND INFORMATION FLOW PROBLEMS:**

As mentioned in the section comparing situation A and situation B, when the meetings were made up of only a few members, the communication problems were practically non-existent.

As a result of this analysis, the first solution to be established is the following:

<u>INTER-GROUP MEETINGS WITH FEW PARTICIPANTS AND ROLE</u>

The presence of few participants in meetings will increase attention and communication. In addition, in order to determine who are the people in each group who should attend meetings, a role will have to be established within each team.

These two measures will solve the above mentioned problem of Situation C in the implementation of AGILE methodologies.

These meetings will be weekly and will be used to discuss with the other groups what has been developed during the week, the future objectives to be developed, the doubts and problems that have arisen and, finally, if there is a need for help between teams, given that the data are interrelated.

Following the Lean methodology on effective meetings:

- A time limit should be set for the meeting, which should not be exceeded. In the event that issues arise that need to be addressed, discuss them with those involved at another time.
- Complete an action plan, in this case a software, or kanvan methodology, could be used to establish what tasks are to be carried out, the actions taken and to follow up on what has been discussed, so that it can then be passed on to the teams.

In summary, the responsibility of the person in this role will be to:

- Secondarily form part of the other teams.
- Attend meetings with the other team representatives.
- Report on the tasks carried out during the week. And future tasks.
- To expose the tasks that need to be repeated and that cause problems.
- Discussing doubts with other teams.
- Be concerned about the activities of the other teams.
- Determine to whom the other teams should turn to from their own team, to resolve any doubts.

MEASURE	***MEETINGS BETWEEN TEAMS WITH FEW PARTICIPANTS***
OBJECTIVE	▪ Increased communication ▪ Increased attention.
MEASURES TAKEN	▪ Meetings with few participants. Fulfilling the effectiveness of Lean meetings. (LEAN). ▪ One representative from each team, team leader.
EXPECTED RESULT	▪ Reduction of information flow problems. ▪ Reduction of data interpretation problems. ▪ Reduction of wasted time and duplicated tasks.

Table 24. Measure solution 1, meetings between teams. Source: selfmade following the literature.

GLOBAL DIVISION OF LABOUR IN PACKAGES

As was already done with the SCRUM methodology in Situation C, the global work will be divided into small packages.

With this measure, we will be able to implement the following solution, a Kanban model to support the Gantt, which was often not fulfilled and did not provide the teams with a vision.

Therefore, the objective of this measure is to provide the teams with a vision of the evolution of the work carried out, with which they can organise themselves, know what they have done and what remains to be done.

In addition, the responsibility of the person who has to carry it out is added to each task, which will increase the participation of the members and control over compliance; tasks will not be duplicated or left undone, as was sometimes the case.

MEASURE	**DIVISION OF LABOUR INTO PACKAGES**
OBJECTIVE	▪ Increasing the vision of the project.
MEASURES TAKEN	▪ Overall division of work into packages. (SCRUM) ▪ Establishment of software with Kanban philosophy (KANBAN). ▪ Establishment of responsibilities. (XP)
EXPECTED RESULT	▪ Reduction of duplicated tasks. ▪ Eliminate the problem of unfinished tasks. ▪ Better temporal organisation of the teams. ▪ Increased participation of the members in the project.

Table 25. Measure solution 2, division of labour into packages. Source: selfmade following the literature.

ROLES WITHIN THE GROUP

Continuing in line with the last comment: "*to each task is added the responsibility of the person who has to carry it out, which will increase the participation of the members and the control over compliance, tasks will not be duplicated or left undone, as happened on certain occasions*".

As a team is made up of between 2 and 6 people to encourage the participation of everyone in the work, it would be interesting to apply roles within the group, it would be interesting to apply some roles of the XP methodology, since as was studied in the previous topic it is a very useful methodology for teamwork and collaboration among project members, especially for small teams of as few as 9 people.

- One of these roles would be the Big Boss, **Manager**, already mentioned for communication with other teams. This could be increased to two representatives per team and they are also in charge of supporting their team. It is very important that they know what is being done.
- On the other hand, **the programmers**.
- On the other hand, **the testers** could be established to make sure that what is being done works.
- Support role, **tracker or trainer**, one of the people who is programming or testing, must also control that all tasks are being carried out and that deadlines are met.

MEASURE	ROLES
OBJECTIVE	▪ Increased participation and internal organisation of each team.
MEASURES TAKEN	▪ Establishment of responsibilities and roles (XP)
EXPECTED RESULT	▪ Increased participation and internal organisation of each team. ▪ Increased communication between different teams. ▪ Improved collaboration and teamwork.

Table 26. Measure solution 3, Roles. Source: selfmade following the literature.

5 CONCLUSION

There is no established methodology for projects in the fourth industrial revolution; everything will depend on different variables such as the type of project, risk, size of groups, etc.

However, it has been possible to establish guidelines and measures on when it is advisable and when it is not advisable to use the different methodologies studied. Moreover, it is very difficult for one methodology to be 100% applicable.

According to what has been studied, hybrid methodologies are currently the most widely used for this type of project. In order to determine which types of methodologies would be used to make up the final hybrid methodology, we have based ourselves on several variables, including the fact that when determining the characteristics of 4.0 projects, they establish the necessary characteristics of agile methodologies.

Therefore, in the project developed by the University of Albstadt-Sigmarigen, it was decided to apply a hybrid methodology made up of agile methodologies.

Finally, it should be noted that the project management currently used is very much based on trial and error studies, given that any new variable can affect the measures taken and it is advisable to continue with a study process for the continuous improvement and optimisation of the management.

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