POLITECNICO DI TORINO

College of Engineering & Management

Masters of Science In Engineering & Management

Masters of Science Thesis

Overview of Industry 4.0 Projects in Different Countries

Supervisor
prof. Guido Perboli

Co Supervisor
Dr. Stefano Musso

Candidate
Muhammad Suleman Murad

March 2019

I hereby declare that, the contents and organisation of this dissertation constitute my own original work and does not compromise in any way the rights of third parties, including those relating to the security of personal data.

Muhammad Suleman Murad
Turin, March, 2019

This thesis is dedicated to my parents for their love, endless support and encouragement

Acknowledgement

Immense thanks to Almighty Allah (God) for making me reach this beautiful milestone in life which wouldn't have been possible without His will.

Most importantly, I would like to express my sincere gratitude to my advisor Prof. Dr. Guido Perboli and co-supervisor Dr. Stefano Musso who allowed me to join the ICELAB at Politecnico, offering a chance to participate in one of today's most relevant conversations in the manufacturing industry. I am thankful for their provision of continuous support throughout my research and a solid presence I could count on whenever in need. Their patience and insightful comments helped bringing this research project to completion.

Table of Contents

List of Figures

List of Tables

Abbreviations

AI	Artificial Intelligence
AMETIC	Spanish Association on Information and Communication Technologies and Electronics
AR	Augmented Reality
CeBIT	Centrum für Büroautomation, Informationstechnologie und Telekommunikation (Center for Office Automation, Information Technology and Telecommunication)
CI4	Connected Industry 4.0
CPS	Cyber Physical System
CPPS	Cyber Physical Production Sytems
DESI	Digital Economy and Society Index
EFFRA	European Factories of the Future Research Association
EpoSS	European Platform on Smart Systems Integration
EU	European Union
GDP	Gross Domestic Product
GDPR	General Data Protection Regulation
GVA	Gross Value Added
HDI	Human Development Index
I4.0	Industry 4.0
ICT	Information and Communication Technology
IDF	Industrie Du Futur
IIC	Industrial Internet Consortium
IIOT	Industrial Internet of Things
IOT	Internet of Things
IT	Information Technology
M2M	Machine to Machine
MEMS	Micro Electro Mechanical Systems
MINECO	Ministry of Economics and Finance, Spain
MVA	Manufacturing Value Added
NNMI	National Network for Manufacturing Innovation
R&D	Research and Development
RAMI4.0	Reference Architectural Model Industrie 4.0

RFID	Radio Frequency Identification
RRI	Robot Revolution Initiative
SME	Small and Medium Enterprise
SMI	Smart Manufacturing Innovation
VR	Virtual Reality

Summary

The necessary premise to discuss Industry 4.0 developments, is to cover complex definitions of what makes it possible, therefore Chapter 1 aims at providing such broad scope where an understanding is developed for Internet of Things and Industrial Internet of Things. These concepts form the basis for Industry 4.0 and aim at improving efficiency and production capability of an industry.

Chapter 2 contextualize Industry 4.0 with the Industrial revolutions that have shaped the current production system, exploring the guiding principles of the matter and the processes and tools needed to implement it. This chapter also talks about GDPR which is an important issue that needs to be addressed by companies before implementing certain technologies involving data.

In the second part of this research, I4.0 policies are scrutinized geographically: where Chapter 3 focus on the current works going on in EU nations (Germany, France, Italy, Spain, UK). The aim of this work is to investigate national initiatives, keeping an eye on how projects and movements come to be. The writer initially gives details of the policies and strategy used by individual country to progress towards Industry 4.0. For each country, the research conducted is being analysed with multiple tools. Graphical analysis is drawn to see how different projects are aiming towards achieving the goals set by these countries.

Chapter 4 is dedicated to the state of the art in non-EU countries, focusing on the initiatives of Japan, USA and China. The idea in this chapter follows similar work and analysis done in Chapter 3. At the end of both chapters a conclusion is also drawn to compare how each country is progressing and the differences that they have to each other.

Chapter 5 is the conclusion of all the study conducted in this thesis and also provides future perspectives on how a country can further progress on different level to reach the major goal towards smart industries and improve their economic level deals with conclusion reports of the successful implementation of Industry 4.0 strategies by specific company, in relation to their geographical context.

Introduction

Since the human progress, manufacturing has gone through many different revolutions of change. It started with the first industrial revolution where steam power and machinal production was introduced. In second revolution electricity and mass production took over and then in the last decade third revolution took charge with introduction of automation and a use of IT.

Western world had faced all these three revolutions where disruptive technology was introduced to increase production capabilities. The fourth industrial revolution, commonly known as Industry 4.0, is now already on its way and is the answer to many challenges faced by the major economies of the world. It is driven by the idea of connectivity, advanced materials, next generation process technology, renewed methods of manufacturing and servitization. The concept revolves around merging the digital and physical world through the knowledge of cyber physical systems. This digitalization of the whole value chain from raw material to the end use is known to impact economy, business model structures and other support functions such as supply chain.

Due to globalization many countries are now positioning themselves to this new revolution with initiatives taken by government or private sectors in the form of medium to long term strategies. This thesis has reviewed and reported the current and present state of Industry 4.0 and its projects across major economies of the world. The goal is to evaluate different initiatives taken by these countries. The document walks through EU countries and then follow into non-EU countries. The writer has conducted a deep analysis of 229 projects from across the world. Each project has been carefully studied and rated based on multiple factors and elements that are necessary part of what one can expect from how industry of future will work.

The findings from this report could provide businesses and industries with a much thorough knowledge about the state of I.40 and how different industries are working to achieve their targets. It also helps in understanding the current position and a future strategy to become more closer towards a digitalized and connected world.

LEFT BLANK INTENTIONALLY

Chapter 1

The Internet of Things

1.1 Introduction

In its simplest terms, Internet of Things is how the everyday objects of use, for example appliances in our houses, are connected to the Internet[1]. A temperature control in a house which is monitored through an application on your smartphone or a machine which tells you when to take medicines or whether you have skipped a medicine, and that could even call an emergency helpline in case you do not respond: these are all examples of IOT based technology.

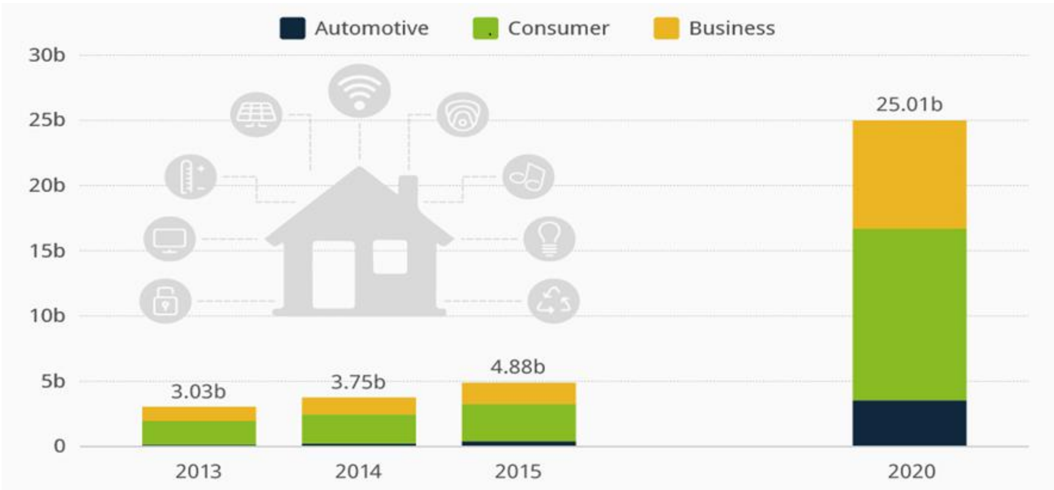


Figure 1 Estimated number of IOT in use worldwide (Source: Gartner)

The Dutch energy supplier Eneco is one such current example where the end user is able to control the heating in their home through an application.

IOT is spreading at a fast pace due to advancements in wireless communication systems[2]. Rapid development in electric technology and smart manufacturing techniques are leading to a transition from digital to intelligent world. The era of Virtual technology through Cyber Physical System is becoming a reality[3-5]. There are variety of things around us for example sensors, smart phones, electronic devices, RFID tags etc. With a unique addressing technique, IOT is capable of making these things interacts and cooperate with each other for a common goal. And this technology has remarkable potentials. The Boston-based start-up company Pillo Health Care has raised approximately $4 million for their home digital care management platform. The aim of this platform is to provide personalized health care with particular focus on adults and elders with chronic illness[6].

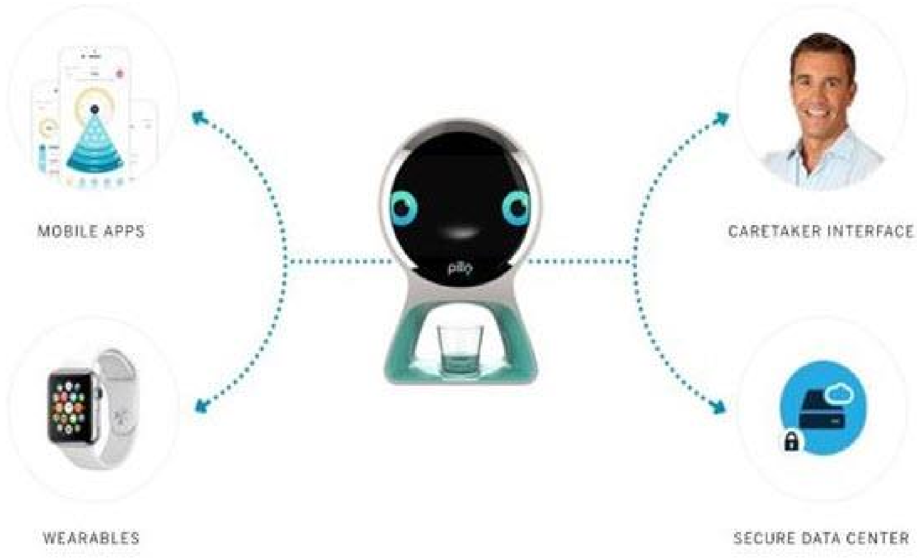


Figure 2 Pillo using IOT

Pillo robot is an in-home personal care robot developed through AI algorithms. Targeted to senior citizens and adults in general, it is a robot dedicated entirely to the health care and well-being of the end users. It can answer questions related to wellness and health care and is capable of connecting people with medical professionals directly. It keeps you updated over the medications, storing and dispensing them. It is so advanced that it can order the refills when needed. Since it is based on AI technology, it is expected that it will work intelligently with growing functionalities related to the home environment it is linked to.

IoT benefits extend way over the providing of services, as it can be extensively seen in the manufacturing industry. Many factories do have machines which work autonomously, one might just think of the extensive use of robotic arms in many automotive manufacturing plants. Business owners now want to take a step further and to see machines interact and talk to each other instead of involving human interaction in order to optimize and speed up production process with minimum risks.

1.2 Industrial Internet of Things:

The main basis of Industrial Internet of Things (IIoT) was to improve the productional capacity and improve the efficiency of operating an industry, and it is expected to bring significant impact on the world economy. Nowadays research proceeds in several directions, to achieve growth in industrial progress. Companies who seek for greater success and to capture a higher market share, will use IIoT with three different approaches[7]:

- Increasing production to gain higher revenues and as a result develop hybrid business models
- Seek innovation by exploiting various intelligent tools and technologies available
- Educate and enhance workforce with new skills

According to Oxford Economics, if we look at the G20 countries, industrial manufacturing accounts for the 62% of their GDP. The potential outreach of highly intelligent automatization is clear, and the range of IIoT industries is wide, including manufacturing, healthcare, transportation, agriculture, logistics, oil & gas and several other utilities. This is also because companies have witnessed higher payoffs from IIoT implementation. It is expected that by 2020 the spending on IIoT will reach to $500 billion while optimistically it is predicted to reach $15 trillion globally by 2030[8].

1.3 What is an intelligent product?

Two things make a device intelligent: sensors to collect data or respond to any change, and a software which works in real time making intelligent decisions based on the data collected through the sensors. There are hundreds of micro electronic control units in a modern-day luxury car and millions of software lines that control various aspects of a car bringing luxury comfort to the customer. Despite the seemingly complicated technology, we consider these products as being just the starting point of an intelligent future.

So how do we perceive an intelligent product of future will look like? The following points identify the characteristics an intelligent product should have:

- It should be able to communicate with fellow products for a common goal
- It should be able to start a task by its own self without any human intervention
- It should be friendly enough to change its user interface accordingly when needed or based on recommendations or from understanding the choices of the customer.
- It should be smarter enough to optimize itself and find ways to lower its operating costs
- It should learn to improve the productivity.
- It should enhance its features with time and intelligently by understanding the routine of its usage by the customer.
- It should take preventive measures to avoid failures and accident and be ready to respond if any failure occurs.
- In abnormal situations it should be ready to respond in way to handle the situation.

To acquire these characteristics there is a need of well-established platforms. IIoT platform is still in research and developing phase to emerge as a dominant need of the industry. Many open architectures are also being developed and available now [9] such as Arduino platform, Raspberry Pi. Although these platforms are being developed by independent producers, to be sold to companies or other operators, there is also a possibility that companies would develop their own platform specific to their own work field. These platforms are then used to analyse big data, create communication links between equipment, to operate the machines and control the operations of various applications.

With the currently available facilities and established technologies, IIoT is divided into three different technological families, that will be analysed in the following paragraphs:

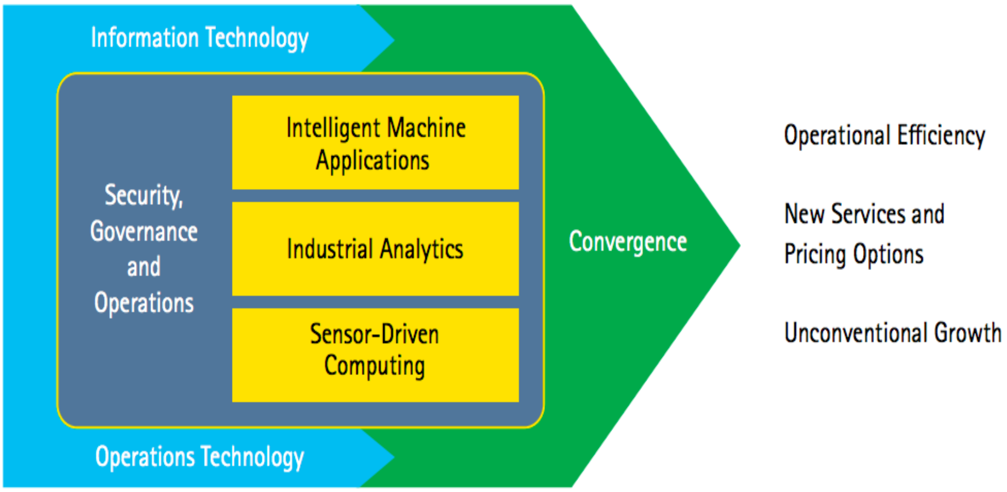


Figure 3 Different IIoT Families

1.3.1 Sensor-Driven Computing

Sensors make objects perceive a physical phenomenon such as temperature, sound, and smell. Computation which is driven through sensors actually converts this physical phenomenon into intuitions. The system and operator then act upon these intuitions.

Example 1: OSIsoft

- It is a realtime data management company which is working on developing a platform that would be capable of collecting data from the sensors and hence controlling the processes involved to improve the production, optimize the processes, sustain and conserve energy and solve any bottleneck issues.

1.3.2 Industrial analytics

Once data has been collected from sensors or other sources, then action needs to be taken based on this data. Industrial analytics transform data into actionable insight based on which decision makers will be able to plan action for the future. Data that once would have taken years to sample and transform into statistics, is now available quickly through cloud-hosted advanced analytics.

Example 2: GE Software

- Predix is an IIoT platform exclusively developed by General Electric Software which it uses for its maintenance business. This platform is capable of providing industrial analytics helping the customers to optimize their systems, reduce downtime of their equipment and avoid risks in order to gain more profit.

1.3.3 Application of Intelligent Machines

The world is moving beyond just manufacturing products. Manufacturers are looking into ways to introduce meaning to a product. This meaning in terms of making them intelligent decision-making products.

Example 3: PTC

- PTC has created a technologically advanced IIoT platform. This platform is unique as it can quickly produce and run new innovative applications for intelligent products which are capable of connecting.

1.4 The Power of 1%

A main objection to the application of IIoT procedures is definitely the costly investment required to repurpose and replace machinery and to implement the necessary technology. As understandable as the concern might be, the risk is to oversee the potential boost in the overall financial well-being of a company.

It only requires a mere 1% in industrial operational costs, and in reducing inefficiencies through IIoT based optimizations, to gain significant profit. [10]

For an aviation company, a 1% cost reduction on fuel per year could lead to saving more than $30 billion. Similarly, $66 billion can be saved such percentage of saving in fuel of gas power generators. This is generally true for all big industries involved in oil and gas, healthcare, logistics and agriculture.

The power of 1% can be visibly a lot in terms of profit and gains for a company who seeks to improve its assets and higher returns per year by investing in Industrial Internet. Industrialists predict that by deploying IIoT, the growth and productivity will grow very high in the future. Ongoing research by academics, industries and government, is spending a lot in this regard to harness all the positive aspects and gains from improving this sector of technology.

1.5 Miniaturization

While we have been talking of these amazing technologies and intelligent communications methods, it would all have been impossible if there was no quick innovation in miniaturization of sensors. Advancement in technology and manufacturing technique has now made possible to develop sensors to be the size of a grain of sand particle. As a result of this miniaturization, sensors can be used in every possible way we can imagine or not yet. They can be embedded in different ways and anywhere. It could be apparels, food packaging, identity documents and in fact our human body.

The interest in sensors have also been a result of embedding intelligence into them. This interest has speeded up the process of miniaturization. Sensors are developed capable of having multi features such as measuring temperature and humidity both based on how they are designed.

There is greater advantage related to sensors that are multifunctional and fully calibrated. This helps in reducing the number of components and sensors needed to be embedded in a system. As a result, design and general costs are reduced, and helps in reduction of the product weight and also size of maybe the PCB.

Miniaturization and its extensive use in related to Industrial Internet can be seen in health and medical industry.

1.5.1 Reed Switch

Reed switch is a passive component. It is basically an electric switch that is controlled with magnetic field. So, it is a device that does not require any additional work or effort or energy, thus making it a very important component with great advantage.

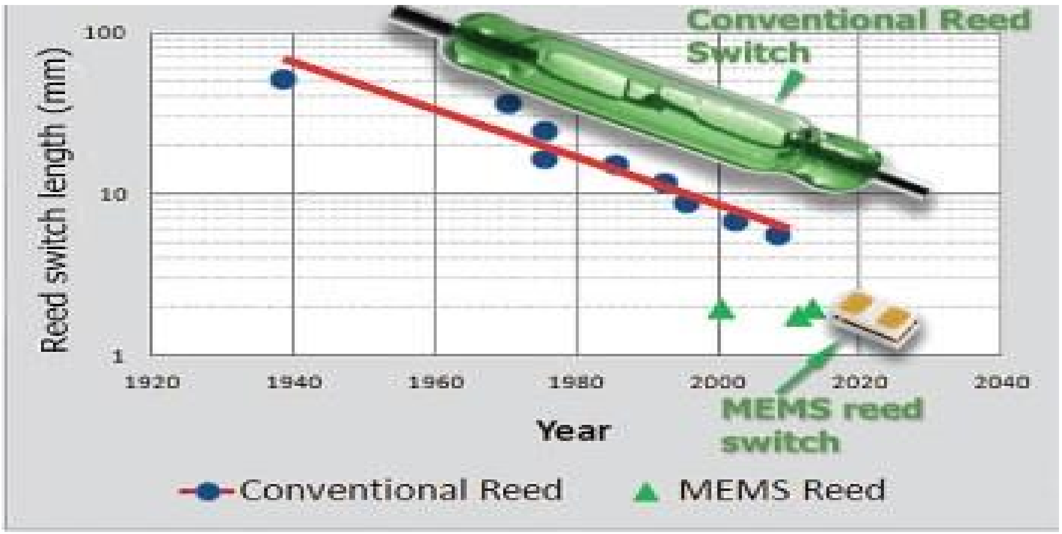


Figure 4 Reed Switch Length over Time

So a reed switch generally consist of ferromagnetic pair of contacts which are normally in open state. When a magnetic field is applied it results in closing the point of contact and once the magnetic field is removed the contacts return back to open position. One of the main problems with reed switch was that it size typically ranged in 25mm size and it was hard to miniaturize a passive component like reed switch. But with improvement in technology and miniaturization, the size of reed switch has been reduced to approximately 3mm. This is a great achievement for such a device and has impacted the industry in a positive way[11].

The use of reed switch is very common and extensive. It can be seen in electronics industries, medical, aerospace designs and many other industrial and non-industrial set ups. Semiconductors, electrics and medical device manufacturers are the most critical areas where miniaturization is of huge importance. Semiconductors require to produce digital pulses at a very high rate every second, maybe billions of times and for this purpose reed switches are important and is why their miniaturization was a huge success for the industry.

In medical industry it is seen to be used in medical implants, used in monitoring devices for glucose level in the body and as outfit pill cameras. We can see reed switch has many uses in very important fields of industry and the best part is that it does not require any energy source to work. Reed based sensors can be embedded in a body for years without requiring any special energy needs or removal while on the other hand semiconductor sensors need source of energy of their power.

Complementary technologies and their success have resulted in advancements of multi and multi-functional sensing systems. This can be observed in devices like smart watches or smart phones. These smart devices have multiple number of sensors and many software that put them into use. Arduino is another important multipurpose electronic platform that can be used to create multi sensor devices. These devices help in linking the physical environment to the digital environment.

Devices like Arduino, Raspberry Pi has increased innovation and use of multi-sensor devices and deploying them into automating many industrial processes and making machine to machine interaction much possible. It is also helping in the advancement of cyber physical systems through creation of many possibilities with the help of IIoT environment.

1.6 Cyber Physical Systems

When a mechanical domain is developed, it is of importance how it will perform its task in the physical domain. Special knowledge is needed in this regard which can most probably come from mechanical engineering field. Many such thoughts and needs are better to be clarified during early design stages to understand if the product will be linked with physical, IT or communication network. If a system needs to have all these three features, then it seems to be a cyber-physical System. So, in simple terms a Cyber Physical System (CPS) is an integration of anything involving some physical processes, digital computation and network communication ability.

CPSs makes it possible to connect the virtual world to the physical world. It means that the computation and software interact through a process management and feedback control system with the outside world. This all leads us to data services and IoT. We can see many examples of CPS in intelligent manufacturing industries. An example of interest would be to consider a production line. In such an intelligent setup the machine performs their task through communication with the individual components and the product that is being produced.

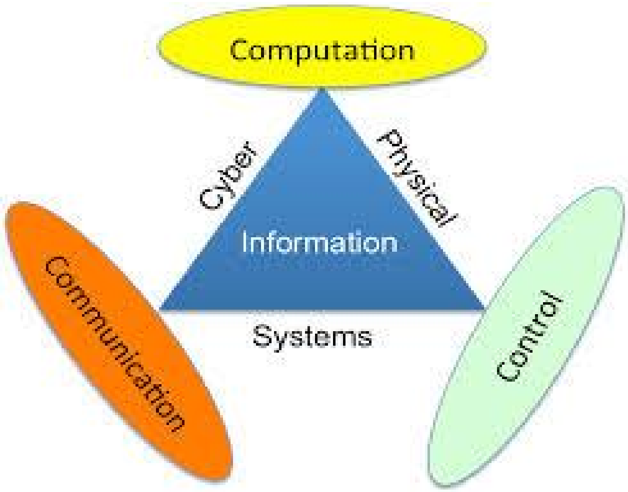


Figure 5 Cyber Physical System

Every CPS consists of an embedded system, which is a digital computing system embedded inside a physical architecture. CPS focuses not only on the physical and digital domain but also the communication network. These systems consist of multiple sensors and embedded controls which monitor and collect data from a physical phenomenon to which they are capable of interacting. This cover a range of data monitoring involving energy usage, heat control system etc.

One of the biggest advantages of CPS system over other embedded systems is that the data collected or used can easily be accessed from anywhere. The data is indeed remotely controlled. The software gives the CPS ability to interact with the physical system anywhere in the world.

A very well-known example of CPS can be seen in robotics. In industrial internet examples of real-world application for CPS are seen in applications based on extensive use of sensor. In such industrialized setup, the CPS monitors a physical environment, process the data and can either send useful information to another network or to an application. Further processing and analysis are performed on the collected data and a feedback is generated where required. In automobile industry, collision detector and protection systems are CPS applications. Considering the pace and speed of technological advancement in cyber physical structure will increase the usage and development of advance CPSs in the future. It would be seen visible improvements in adaptability, smartness, functionality and usability of such systems.

1.7 Cloud Computing

Cloud, a relatively common word and rather a cliché but when combined with the term computing, it really makes it meaning beyond the scope of common understanding [12]. Something big and fuzzy. It is something that is much needed by the IT sector. So, what does the IT professionals really need and how it makes cloud computing so much important to them? Well this fuzzy term gives the IT giants a way to increase their capacity and enhance their capabilities to higher level but at the same time without putting huge investments into new products, infrastructures, training workforce or licensing more software.

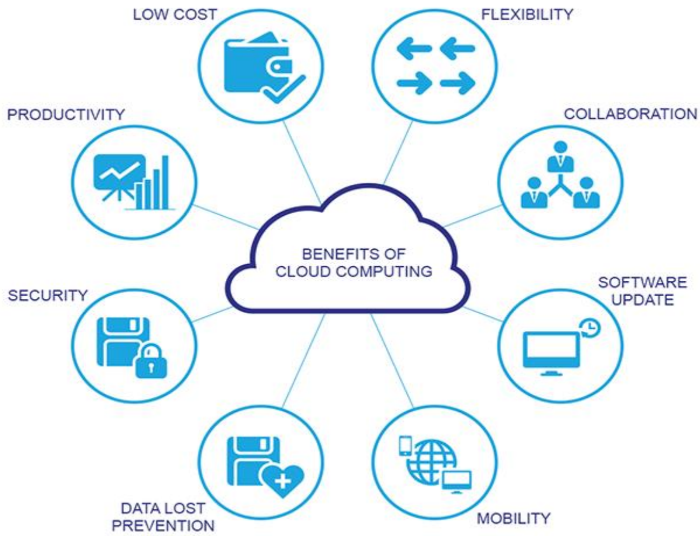


Figure 6 Benefits of Cloud Computing, (image courtesy: Visiontech Systems)

Cloud computing is an important tool for Industrial Internet. Without compromising the financial resources, it fulfills the performance need of industry and provides the expanding infrastructure needs. With all these advantages that we see coming through with cloud computing there is still a problem which needs to be addressed. It is Latency, it is the time which is needed to transmit and process data from the device to cloud. Once the data is stored then it goes through deep analytics with Big data. This time is not acceptable in many cases as industrial processes are fast paced and real time data carries significant importance.

Since industrial scenarios and specifically manufacturing industries require real time process of data, for such industries a public cloud computing is not a good source. Hence a hybrid or private cloud would be a better option as it can also result in better data protection. But indeed they also come with some drawbacks as self-managing a private cloud could be costly and if it is not something a company is used to could create problems rather than benefits.

1.8 Big Data Analytics

Any data that cannot be managed by traditional methods of database and that cannot be processed through normal tools is considered Big Data [13].

A huge combination of data coming from different sources such as text, blogs, web services, online forms etc. for the large data structure for big data. This data can be either structured or not. One of the major concerns for IIoT is to handle a huge amount of data, specifically that data which is unstructured. Also, to note that there is a huge collection of data which comes from M2M interaction and the sensors data from many devices.

In order to make meaningful information from this huge collection of data there needs to be better and proper ways to manage and handle it. The advancement in miniaturization, nanotechnology and communication technology has let to development and heavy use of micro-electromechanical Systems (MEMs). All of these developments are another reason for such a huge amount of data all around within even a single industry plant.

Figure 7 The 8Vs of Big Data

Hence it can be noted that as a result IIoT relies heavily on Big Data and requires next generation of techniques to handle this. Cloud computing is available for industries which manage such data for them with unlimited storage capacity. There is also an open source technology known as Hadoop. Hadoop is a cloud based data storage system which is optimized in order to handle data whether it is structured or not.

Chapter 2

Industry 4.0

2.1. The History of Revolutions

Industry 4.0 is an insightful change of business models due to connection of physical world with the cyber world and the advance use of digitalization, automated process and robotics in manufacturing processes [14]. In a more simplistic way we call Industry 4.0 as a self-regulating production system based on autonomy, knowledge and sensor data [15]. According to the German federal ministry of education and research, Industry4.0 will have machines, equipment and other autonomous components which would be able to exchange information in real time despite any distance [16].

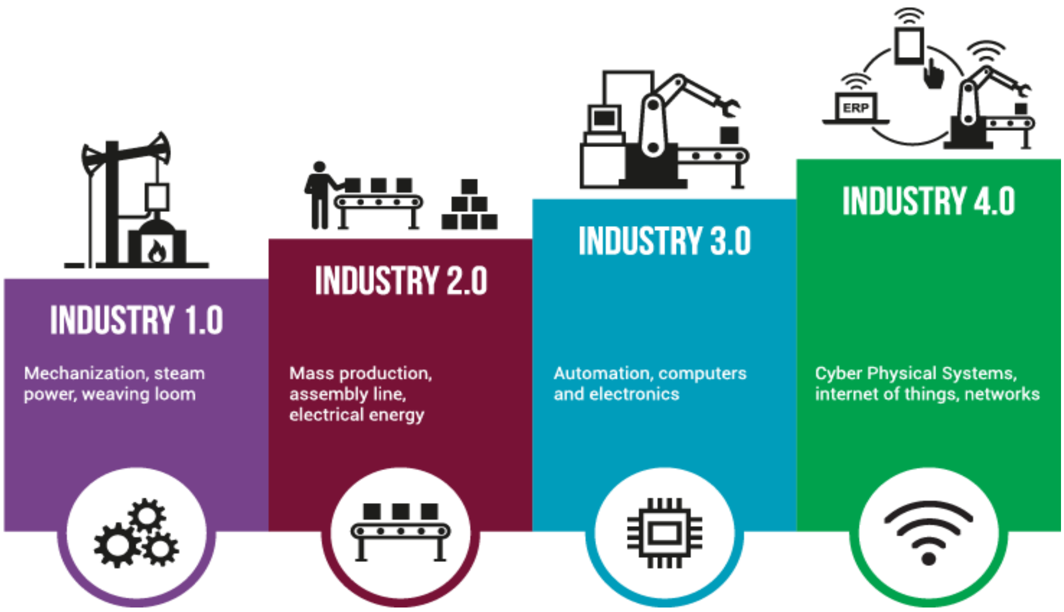


Figure 8 The industrial revolution over time

Industry 4.0 can be tentatively compared with three industrial revolutions that occurred in the last centuries for approximately 200 years and represented the main disruptive changes in manufacturing that have resulted from several technological advances over time [17].

Below we look at the three industrial revolutions which changed the way of life during its time.

2.1.1 The First Industrial Revolution – 1765

The time period of first industrial revolution spans from the end of 18th century to the start of 19th century. This was observed through the emergence of mechanization process in weaving looms in England. As a result of mechanization the agricultural methods and family based old fashion business were replaced by mechanical processes making a foundation for the industrial economic structure and big factories. Pit coal and steam was then used during process instead of wood.

The period was called as mechanization age. Steam played an important role as energy generating source. Steam, coal and iron along with other raw materials accelerated the development of railway structure. This made transportation of raw materials and other products much easier and in huge quantity. Hence, as a result, the industrial revolution spread to Europe. Major inventions took place such as those related to forging and other material shaping processes which indeed formed the blue prints for the first industries. This revolution was an important step towards human economic development and led the world to become more interconnected and smaller.

2.1.2 The Second Industrial Revolution – 1870

While approaching the end of 19th century, the human race saw many advancements in technology and as a result there was emergence of new sources for energy in terms of oil, gas and electricity. Electricity began to be used in production systems. Assembly lines were developed and first usage occurred for slaughterhouse at Cincinnati, USA in 1870s.

Monorail trolleys were used at the slaughterhouses for the sliced pieces of meat. A pulley system was used to bring meat to different workers. In the years following this development, Henry Ford got interested in the idea and decided to implement it in his car manufacturing industry. Ford's development of production line in automobile industry and the increasing usage of electricity in factories saw rise and advancements in industrialization. As a result, social and economic structure started to change significantly. Steel industry saw a growth and development as its demand grew. Invention of telegraph led to new and revolutionized methods of communication. The result of these inventions saw a capitalized structure of economy and industry based on large industries. While the first industrial revolution saw spread in UK and Europe, the second revolution as a result of greater inventions in transport and communication spread to countries like Japan and American.

2.1.3 The Third Industrial Revolution – 1969

During the second half of the 20th century, a revolution was seen in terms of automation of production processes. The first two revolutions were referred to as mechanization and serialization respectively. New type of energy potential sources emerged with a powerful potential compared to others such as Nuclear based energy. This period saw rise of electronics with development of microprocessors and transistors. Scientific development was witnessed such as computers, optic fibers, laser, biopharming and bio genetics. Telecommunication were moved to next level of technology. Miniaturization of products opened new doors of research. As a result of this revolution automation was possible due to programmable logic controllers and robots. This is also the period which led to rapid depletion of earth resources and made thinkers sit to develop rules and regulations for sustainable approach towards protecting the ozone layer and green house affects.

2.2 Why industry 4.0 and why now?

Mechanization of production took place during first industrial revolution using water and steam, second revolution was a result of development in electrical energy which resulted in mass production and renewed ways of transportation while third revolution saw automation of production as a result of advancement in IT and electronics.

The world now is progressing at a much faster pace and as a result we are observing a fourth industrial revolution which seems to take third revolution a step further by merging it with digitalization. Different technologies are brought together and as a result the line between physical, digital and biological world is blurring. These revolutions in different aspects of technology and life are transforming the production mechanism completely. As a result, there is also research and changes in management and governing systems.

2.3 Design principle of Industry 4.0

Intelligent networking is a key element behind Industry 4.0. The whole value chain revolves around creating a network where machines, systems and production units are all interconnected to each other. They are capable to communicate with each other when needed or work autonomously in a cohesive way without human interference. Here in this topic we highlight the main design principles related to Industry 4.0 which can be used by industrialists and manufacturers to automate and digitalize their production procedure.

2.3.1 Interoperability

In a traditional production process, there is a set of methods and rules to carry out a task. It involves people, some machines and well determined process. Interoperability is something very different. It takes charge of the whole environment of the production process where there is flexible interaction and collaboration between various types of components involved in the production process. It means that every component involved can connect with the other, communicate and perform various operations and functions through the industrial internet of things.

2.3.2 Virtualization

Sensors are one of the most important elements in connecting physical world to the virtual world. Sensors collect the data from the actual physical world related to process activity and different aspects related to a particular work task. This data is then linked to a virtual world where the physical world is simulated in a virtual reality. Designers and engineers use this simulated world to understand the process, customize or carry out tests and upgradation in the virtual setup. This all is indeed possible with complete isolation or alteration of the physical process thus reducing the risk or heavy financial costs.

2.3.3 Decentralization

Decentralization under Industry 4.0 means that within an intelligent manufacturing system all the components involved can autonomously work and take decisions. While these decisions are autonomous, but the aim is to keep the organizational goals and values intact and to work with similar intension.

2.3.4 Importance of real time

Industrial work happens at fast pace and hence when it comes to Industry 4.0, data need to be collected and processed quickly and in real time. Monitoring, feedback and storing of all data must be achieved in real time.

2.3.5 Service Orientation

While we move towards higher level of automation and smart industries through internet of things, it is still of great importance to take care of services[18]. These services, both internal and external are a key component of progress and success in Industry 4.0 implementation that needs to be understood.

2.3.6 Modularity

If a design is flexible, then it can help in easily adapting to changing requirements and circumstances on the shop floor. Modularity is another key principle of importance to Industry 4.0. If the production systems, the conveyor belt and other modules of production are flexible and agile then the industry can easily manage and response to any change and build products at a faster pace than others. Modularity also requires that the production line can be upgraded by replacing or expanding it without halting the daily activities of the industrial production process.

2.4 Building blocks for Industry 4.0

While some of the building blocks for industry 4.0 were explained in the previous chapter. Here we quickly outline the major tools that lead us to a complete understanding of Industry 4.0.

2.4.1 Big Data and Analytics

Manufacturing industries are progressing due to both minimization and extensive use of sensors and software systems. As a result, a huge amount of data is being produced both structured and unstructured. This data carries great information from the production process and other aspects of manufacturing. This data needs to organize in an orderly manner to collect important meaning from it and use analytical techniques to make important decision wisely.

Data analysis is very important, for example it can help to identify different phases of production process where there is redundancy and hence decisions can lead to streamlining it.

In Industry 4.0 there are 6C's associated with Big Data analytics:

- Cloud Computing, related to storing and using data over the cloud
- Connection, related to sensors and different networks
- Cyber, it is also related to memory and modelling
- Context, content which is important to data collected or used.
- Community, the way how stakeholders are connected and data is shared in between people related to the work
- Customization

2.4.2 Autonomous Robots

Robots have been in use since a while now. Robotic arms are one of the most important machines used in many industries and particularly in automotive. A lot of research has been seen around the world to improve the quality and evolve how we perceive the robots of the future. Huge investments are being made also and the results are fruitful. The researchers and creators of robots want to make them intelligent, smart, autonomous and able to create interaction so that there is no need of human for the functionality of a simple robot.

2.4.3 Simulation

From applying traditional methods of trial and error which resulted in higher costs and long process, Industry 4.0 enables the expanded use of virtualization. A virtual world of physical world is used to test and apply various advancement without interfering with the real world. These simulations help in better understanding the possible outcomes and once a solution is achieved virtually then it is easy and less risky to implement it to a real physical model.

2.4.4 Horizontal and Vertical System Integration

Integration is also a key element of Industry 4.0. The goal is to have the IT and operating technology fully integrated into a single unit. This means that from engineering production to marketing and after sale services shall all be closely working together. With automation, big data networks and networking the value chain itself becomes automated.

2.4.5 Cyber-Security

Industry 4.0 works through industrial internet of things. With all the features that Industry4.0 have to offer also put a lot of data and critical information into the cyber world. This situation brings some negative aspects of cyber threat as there are increasing vulnerability to security online as had occurred in past during 2015. Data of personals is also very important and that put a lot of burden on companies to ensure that each critical data is secured. EU in 2018 passed the General Data Protection Regulation, in coming topic it will be discussed in detail how GDPR will affect Industry 4.0.

2.5 RAMI4.0 Architecture

Reference Architecture is the specification of what language one should use to describe a system.

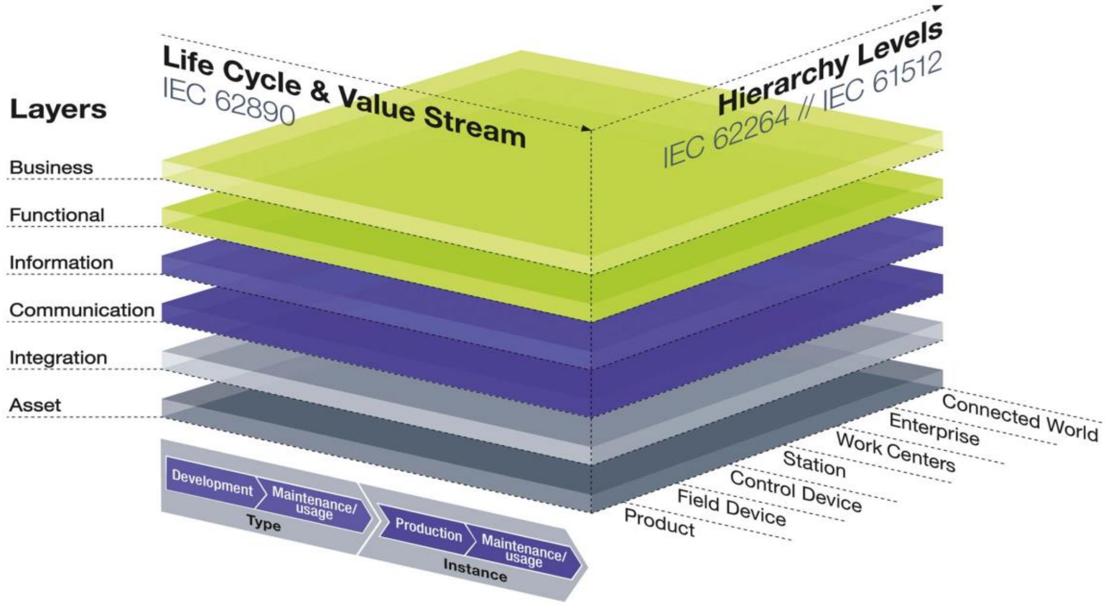


Figure 9 RAMI4.0 Architecture

Given the current resources, companies will realize the concepts of Industry 4.0 with the available technology and equipment's already in hand. So the main challenge for industries is how to utilize the already available standards and integrate them into new concepts.

It was Germany who addressed the issue of standardization by developing the RAMI architecture for Industry 4.0. RAMI architecture take its basis from the Smart Grid Architecture which was introduced in 2014.

The Industry 4.0 Reference Architecture (RAMI) is a three dimensional map which addresses the issues in a more structured way. It is a service oriented architecture which integrates and brings together all the elements and its components in a layered and a life cycle model structure.

The architecture organizes the life-cycle/value streams and the manufacturing hierarchy levels across the six layers of the IT representation of Industry 4.0.

RAMI4.0 is expected to:

- Identify existing standards
- Identify any loopholes in the existing standard and remove them
- Identify overlaps in the existing standard

The three different axis of RAMI4.0 structure are defined in following figure.

Three Axis of RAMI4.

- Layers - The Architecture
- Hierarchy - The Factory
- Product Life Cycle and Value Stream

Axis 1: Layers- The Architecture

Layers takes the vertical axis of the RAMI4.0. It covers different perspectives such as important data, business processes, critical information, communicational behavior and assets [19]. This is related to IT where complex network of a project divided into manageable and understanding parts. Following figures explains in short the different parts of it.

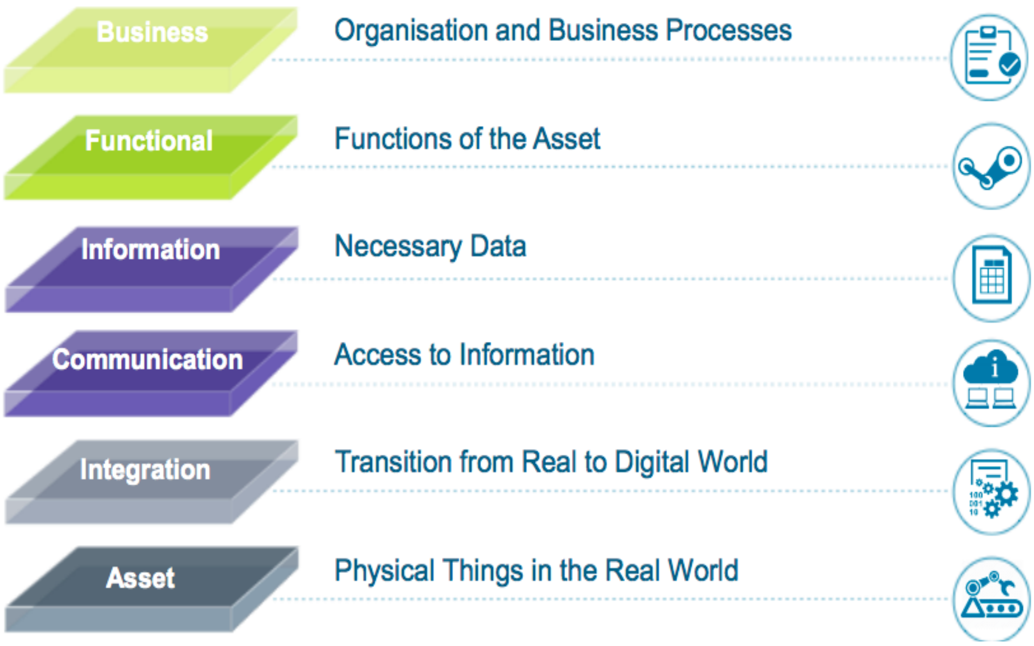


Figure 10 Axis 1: The Layer

Axis 2: Hierarchy: The Factory

Hierarchy is an important criteria to study in relation to Industry 4.0. It lists the functions and responsibilities inside a plant or factory. This functional based hierarchy is different than the classical automation pyramid and not related to equipment classes. It defines various circumstances inside an Industry 4.0 structure through functional classification.

This axis follow the IEC 62264 and IEC 61512 draft when dealing with the functional assignment and classification within a factory.

This hierarchy covers many sectors from products, control devices to work stations, as can be generally seen in the figure 9.

Figure 11-A general representation of functional connectivity within Hierarchy

While the two IEC standards mentioned only cover the levels inside a factory unit but Industry 4.0 goes beyond. It deals with rather group of several factories involved for a common goal and other external engineering firms, suppliers and customers. The *enterprise* and *connected world* are added as a result to represent the level beyond the factory floor.

Table 1 comparing the previous and current trend

Industry 3.0	Industry 4.0
• Hardware-based structure	• Flexible systems and machines
• Functions are bound to hardware	• Functions are distributed throughout the network
• Hierarchy-based communication	• Participants interact across hierarchy levels
• Product is isolated	• Communication among all participants
	• Product is part of the network

Axis 3 – Product Life Cycle and Value Stream

Product life cycle is the different phases a product goes from its design to use and finally when its withdrawn. Product life cycle is vital part of Industry 4.0 [20].

Industry 4.0 is not limited to just manufacturing and developing of smart products for consumers but it also revolves around the machinery, plant and the power supply units. Hence in order to achieve the quality of Industry 4.0, it is necessary to digitalize and integrate industrial value chain with the complete product lifecycle. Hence all data from product development, to maintenance usage, production, and finally sales and marketing will be approached and accessed in better way. Data regarding a product, from the initial idea and production to sales and marketing. IEC 62890 draft is one of the good guidelines when dealing with product life cycle. To this, it is of utmost importance to understand the difference between *type* and *instance*.

Type

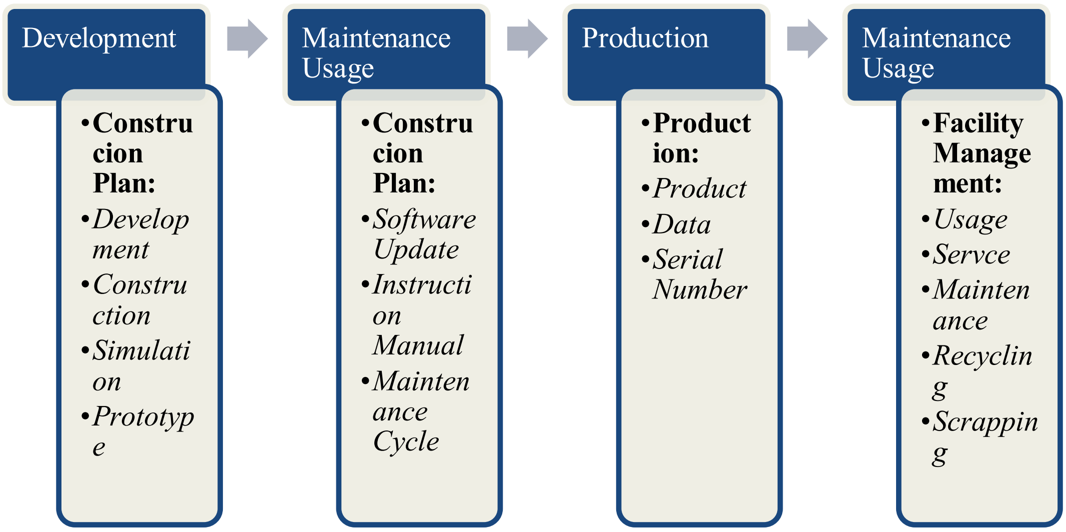
Basic idea of the product leads to its type. This segment covers from design orders being placed, to development and testing which is conducted and finally to the initial prototype produced. Thus during all these phases, the type of products, machinery etc. is created. Once all the test are conducted and everything is validated, then the type is released for regular production.

Instance

Once the type is released, the products start to manufacture on industrial scale. Every product which is manufactured shows an instance for that type, for example the product might be carrying an ID bar code number or a specific serial number. The products are sold to customers as instance. Once the customer gets the product delivered to them it again becomes a type. After they are installed into a particular system, they become instances again. This conversion keeps on repeating several times throughout the change of system. There is a continuous phase of feedback and improvements are reported from the purchased products because of which the manufacturer amend the type documents. The new documents lead to manufacturing of new and improved instances.

Value Streams

A huge potential of improvement can be seen by digitalization and integration of value streams in Industry 4.0. As a result of such advances, logistical data can be used on the assembly lines and the order log can be used to organize intralogistics. Due to real time, data purchasing department can be aware of inventories at any moment of interest. The customer can also be aware of product order. Integration of all these actors of production, logistics, maintenance, supplier and customer results in huge improvements of the whole value stream. Therefore, product life cycle in Industry 4.0 doesn't have to just look at the performance improvement within single factory but rather collectively at all the stakes and parties involved in the whole process from engineering, suppliers to final customer.



2.6 GDPR and its Effect on Industry 4.0

Advancement in science and technology and adopting to latest trend to make businesses spread easily across the globe, huge corporate industries are relying heavily on IT and cyberspace. Due to great opportunities offered over the cloud, the cyberspace is getting occupied by influx of many modern ventures and industries. This has led to increasing threats being offered in cyberspace which needs to be considered by every entrant and all companies relying their business models with data stored on cloud [21].

If we look at Industry 4.0, we can see that it is heavily driven through big data. This means a lot of sensitive data will need to be stored through cloud computing and a greater use of cyber space. This will affect the whole business model of the company involved, the data of its customers and assets. With privacy regulations emerging in EU known as the GDPR (which will be discussed in following paragraph), data minimization might be needed. The question that emerges for companies is how to develop a trade-off, in order to reduce the data or reduce the quality content collected, and while this is being done, how to keep the main goals of Industrial 4.0 intact?

2.6.1 Data Protection

Data protection has become a crucial topic of time. This protection can be related to personal data, corporate data, business data and industrial data that carries sensitive information or any information that can have negative impacts if leaked or misused.

2.6.2 What is GDPR?

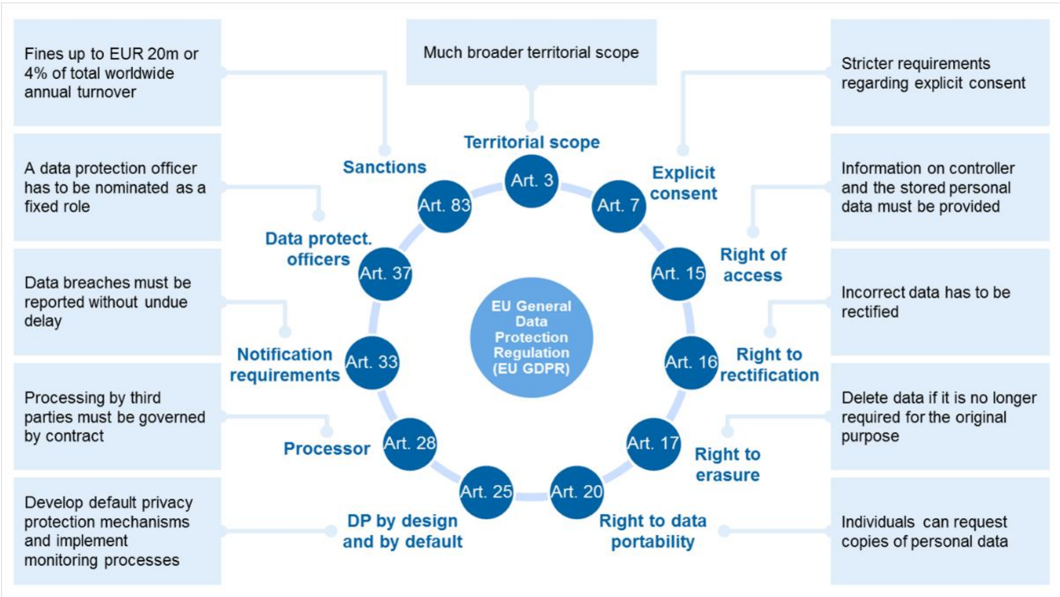


Figure 12 A brief outline of implementation aspects (Courtesy: Business Hub)

General Data Protection Regulation (GDPR) was adopted by European Union in April 2016 and came into effect all over EU on 25th May 2018. It is a legal based framework with guidelines on how to collect and process personal or sensitive information related to EU citizens [22].

It details the rights of individuals, principles on how to manage data and legal revenue-based fines in case any company fails to comply in certain matter such as misuse of data. It is of particular importance for those institutes which deals with huge data, such as banks, corporate structures, industries and other financial companies. It is also a requirement now to have consent before collection of data and to notify if there is a sudden breach or hack. In order to have a proper working data protection department, dedicated officers must be included.

2.6.3 How can Industry 4.0 react?

In order to compliant with the GDPR requirements related to data protection, a company needs to address and work out its corporate structure internally and externally. The internal structure could involve, important data of staff, and its management and protection. The external structure could involve, the contracts and agreements with other business partners or customers, suppliers' data and many public policies devised by the company. This all can make a company supervised in a much better and effective way controlling its cyber space [23].

A company in 2020 will compete on various factors. While it will need to show its competitive gain through better products and services at the same time it will need to clearly demonstrate and create trust with its consumers including business partnerships, contractors and suppliers that their cyber security is of high level and that they are up to date and accountable with data security laws and regulations.

This all leads to when Industry 4.0 comes into action, where there is a high and extensive network of IT tools and their integrations, a large number of sensors, robot's usage which are powered with artificial intelligence tools. AI means a huge data being stored on a regular basis. Product efficiency results from this integration of IOT, CPSs, big data and cloud computing. Industry 4.0 also works on generating important trends from data analytics, understanding data it collects to predict market situation in order to drive its business model more successfully and provide better services and products. But this all comes with bigger challenges faced in terms of data protection. The whole data collection enables profiling of data subjects which is in fact a technique regulated by the GDPR.

This ultimate transformation doesn't need to be sudden and this is why it is referred to as 4th revolution. Industries need to study their current structure and processes, understanding how data is processed and where is it stored. It should understand the flow of data within its systems. Education of employees is critical to data protection. Hence employees should be educated on the renewed challenges faced in terms of data protection, cyber security and awareness on how it works.

It is important to understand the problems and remove and misunderstandings first. Once these measures are adopted by industries, only then they can proceed to technological part. But the whole understanding part of how to comply with GDPR is a significant progress in the path of data protection which is an important base in order to adopt Industry 4.0.

2.7 Government Roles

Industry 4.0 is penetrating the social, economic and political landscape and due to globalization of economies many countries are trying to position themselves in the global market.

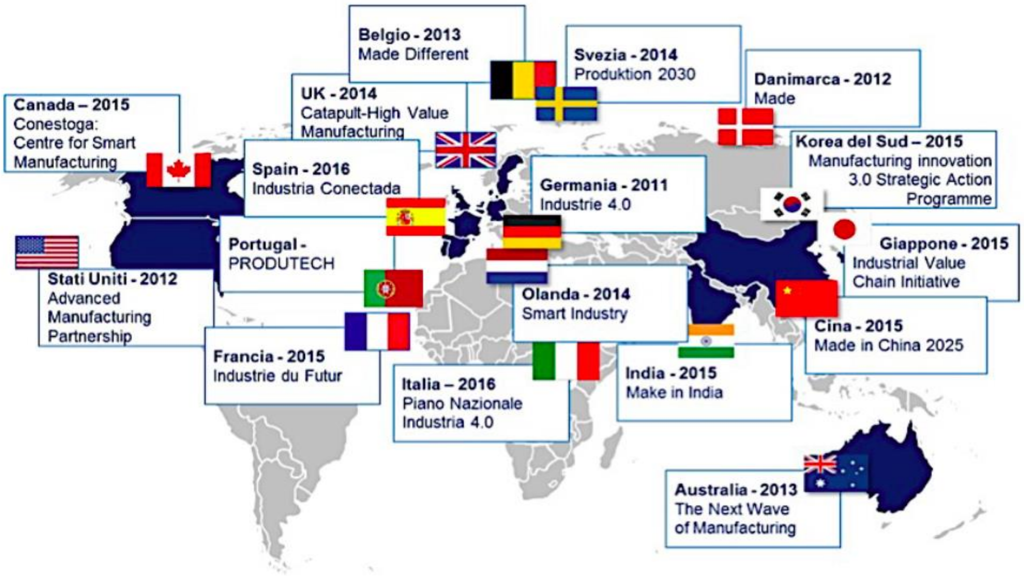


Figure 13 Initiatives taken around the globe

Many governments led initiatives have been introduced around the world to ignite this transition. German manufacturing was the major power drive behind initiating industry 4.0 [24]. Since then, the concept has been widely acknowledged and accepted by many EU countries who are establishing their own commitments towards the wide goal. Countries like China, India and USA are also driving their attention towards this rapidly advantageous talk.

2.8.1 Horizon 2020 initiative

The EU has paid a special initiative by launching a program in 2014 called as the Horizon 2020.

"With 80 billion of funding, Horizon 2020 is the largest EU research and innovation program with these funding available for over 7 years (2014-2020). Horizon 2020 is the biggest EU Research and Innovation program ever in addition to the private investment that this money will attract. It promises more breakthroughs, discoveries and world-firsts by taking great ideas from the lab to the market" [European Commission][25]

The objective of Horizon 2020 is to ensure development of world class scientific tools, remove or reduce barriers towards innovation and boost the public and private sector to cooperate towards innovation.

Outside Europe different initiatives are also taking place with heavy investment being made by USA and China. Shortly the countries will be analysed individually.

Chapter 3

European Union & Industry 4.0

3.1 Introduction

Europe has always been one of the world major center of innovation. The EU market which consist of 28 states account for 0.5 billion of inhabitants, making it largest single market of consumers worldwide. Economy is just one of the aspects of EU. EU's founding principles are based on freedom, peace, equality and indeed democracy [26]. Economy, technology and social progress is all part of these founding principles. Since its formation, the success of EU in terms of economy has always lied in the Human development Index (HDI). There had been a solid and well-functioning welfare system offering social security, community participation in activities around EU and social development through well-developed education and technical programs. This all made a strong basis from creativity and economic development compared to rest of the world.

With the growing trend of digitalization these indexes become even more important. Innovative policies need to be established and implemented at a faster pace. For EU this means three things: More innovation, more Europe and more coordination [27].

A convincing strategy and road map are next step in development for future, but such things need to be reflected in budget as well as national initiatives by the respective countries within EU. This means investment in innovation must be significantly increased. In this chapter we will discuss about the different initiatives taken by EU as well as countries that comes under EU, in order to achieve the targets, they have set so far.

3.2 European Innovation Policy with A View To Industry 4.0

Since last couple of years, the EU has been using the slogan of *Advanced Manufacturing* when addressing the topic around Industry 4.0. Technology has been considered of fundamental importance in order to address the problems associated with increasing economy and creating more jobs. Various research papers and publications were studied to understand the strategic roadmaps by European commission and then a comparison was drawn with roadmaps before

2011 period and after 2011 period [28]. This includes the effects of industry 4.0 which falls in the after period of 2011.

Table 2 Analyzing Strategic Roadmap before and after 2011

		Before 2011				After 2011			
	Reference	[33]	[29]	[31]	[34]	[35]	[32]	[30]	[36]
Technologies	Internet of Things	x		x	x	x	x	x	x
	Robotics	x	x	x	x	x	x	x	
	Embedded Systems	x	x	x	x	x	x	x	x
	Cyber Physical Systems				x	x		x	x
	Cloud Computing				x	x	x	x	x
	Additive Manufacturing						x	x	
	Agent Based Systems				x	x		x	
	Sensing	x	x	x	x	x	x	x	x
Design Principles	Virtuality	x	x	x	x	x	x	x	x
	Decentralization			x	x	x	x	x	x
	Real Time Analysis & Decision Making	x	x	x	x	x	x	x	x
	Connectivity	x		x	x	x	x	x	x
	Modularity	x	x	x	x	x	x	x	x
	Service Orientation	x	x	x	x	x	x	x	x

Looking at the table above we outline that the roadmaps before 2011 did consist of the idea and technologies related to Internet of Things, robotics, embedded systems and sensing, so it is clear that such technology did not propagate due to emergence of technologies leading towards Industry 4.0. We also observe that additive manufacturing and agent-based systems became prominent in roadmaps after 2011 but not very extensively, the reason could be specific limitation of their applications. A very well understood insight was extracted when comparing the two important roadmaps which was issued on Smart Systems Integration before and after 2011 by the European Technology Platform. EpoSS (Strategic Research Agenda of the European Technology Platform on Smart Systems Integration) and EFFRA (Factories of the Future PPP). The roadmap after 2011 by EPoSS [30] presents the emerging technologies in cloud computing and

CPS which is very much in line with Industry 4.0. Studying the roadmap of EFFRA [32], we did not observe CPS being addressed but there is reference to cloud computing and additive manufacturing. The reason could be that EFFRA latest edition was published in 2013 while that of EpoSS was published in 2017. In the design principle, important observations were made. Almost all the design principles were found in all the roadmaps before and after 2011 except for connectivity and decentralization. This means that many design principles had reached a mature state so that they could easily integrate with latest technologies for applications and could be easily materialized under Industry 4.0 concepts.

In 2013 a taskforce was established which presented the European Commission 2014 document detailing how to deal with the challenges related to declining portion of manufacturing in the EU GDP. Through a publication titled, “For a Renaissance of European Industry” for industrial policy [37], the commission pressed on how the digitalized technologies for example, big data, cloud computing, IIOT, smart industries, robotics, automation and advanced printing technologies such as 3D are all important conditions that are necessary in order to increase the productivity of the EU Manufacturing industries.

Through the Directorate General for Internal Market, Industry, Entrepreneurship and SMEs (DG GROW) several activities and strategic goals were set to increase GDP of industrial output from 15% to 20% [30].

Overall the European Commission explained three objectives:

1. Advanced Manufacturing technologies to be commercialized at a faster pace
2. To reduce the demand shortfall for such technologies
3. Promotion of skills related to these technologies.

3.3 Re-Industrialization of Europe

As mentioned in chapter 2, in 2014, EU initiated a new research program of Horizon 2020, where through a funding of €77 billion a major plan was developed involving research and industrial innovation which could result in key technologies. We can see that such a policy was needed to use innovation as a key measure to re industrialize the EU. The objective in terms of industrial manufacturing is to increase the share in GDP from 15 to 20 percent by 2020. But a point of consideration is to understand that this value of GDP varies significantly between the member states from 24.8% in Romania to just 5.3% in Luxembourg [30]. Germany on the other hand belongs to one of the countries with highest proportion of industry.

With the aim of promoting digitalization of industries many regional and national initiatives have been launched since Horizon 2020. Through EU commission the best practices can be shared creating a great advantage of building better skills, qualification and a uniform standard.

Table 3 Estimated investment in the digitalization of European industry [30]

2016/2020	EU (ongoing or planned)	Member states	Industry
Digital Innovation Hubs	€500 million (from Horizon 2020)	€5 billion (ESIF, regional budgets)	ca. €17 billion
Public-Private- Partnerships	ca. €4 billion (from Horizon 2020)	nearly €1 billion (contribution for "Electronic Components and Systems for European Leadership (ECSEL) Partnership")	
National policies/ digitalisation strategies		€15 billion (planned national digitalisation programmes)	
Important Project of Common European Interest (IPCEI) on Electronics – planned	€300 million contribution for the Electronic Components and Systems for European Leadership (ECSEL) Partnership	€1 billion from member states (e.g. France, Germany, Netherlands, Italy and Britain)	€5 billion
European Cloud Initiative	ca. €2 billion from Horizon 2020 are being invested into the European Cloud Initiative	€4.7 billion in additional resources from private and public sources for European data infrastructure	

There are four long term prospects and paradigm shifts associated with Industry 4.0 which aim to change the manufacturing industry landscape of Europe [38]

1. A regular estimated investment to digitalize the nature and factory structure of European Industry. This means improving the process, making efficient use of resources and other sustainable manufacturing techniques in line with digitalized process.
2. Factory and its local community. This refers to increasing the geographical closeness and integrating customers in the design and manufacturing phase of the process.
3. Value chain. A collaborative process to make the manufacturing process more responsive and distributed. This will enable mass customization of the products and services being offered.
4. Factory and its relationship to human. This refers to improved working conditions under the roof of the factory and the different possible human oriented interfaces.

3.4 Analysis of EU Countries

To continue further in this chapter, we will discuss the initiatives taken by the most prominent European Union countries and their current status in both educational research and practical implementation.

3.4.1 Germany

In July 2010, The German federal government released an action plan known as High Tech Strategy 2020 [39]. This plan highlighted 10 points agenda and Industry 4.0 initiative is one of them. The idea of this strategy was to make Germany a leading supplier in products of different categories. Since then research and innovation has been growing massively in Germany's political agenda. There is a higher engagement in industry, politics, research and people due to a well rooted belief that investment for future has always ignited the best economic and entrepreneurial tools in order to overcome the difficult periods associated with economy and hence achieving a higher growth and strengthening of economy.

This plan is a very unique and a well-rounded approach to orchestrate the government policies, academic policies, improvement in research institutions and radical innovations of industries in Germany in order to make it globally a market leader in advance technology. In 2013, as a result of this strategy many business associations like BITKOM, VDMA and ZVEL were encouraged to establish Industry 4.0 platform known as Plattform Industrie 4.0 [40]. With the support of Ministry of Economic Affairs and Energy and Ministry of Education and Research, in 2015, it expanded even further. Later it was joined by different business associations, private sector, research organizations, unions and other political institutions. Nowadays more than 300 players from 159 organizations are actively working on Industrie 4.0 and this number is expanding [41].

Industry 4.0 can be seen as a rescue tool to expand the traditional values of Germany manufacturing industry and strengthen and raise its international position through internet-based technologies by selling or licensing machines or plants throughout the world.

Over these past few years the Federal government of Germany launched many technology related research programs. Model factories were setup, centre of excellence was developed, and other corporate projects were initiated in different parts of Germany, example in Baden-Württemberg, Berlin, and North Rhine-Westphalia. These centres are working on developing production technologies and their related applications.

Together with the high-ranking representatives from business sector, labour unions and science, the Economic Ministry and Research Ministry oversees and manages the Industrie 4.0 platform. Expert groups on specific topics have been formed and tasked with developing operative solutions to problems regarding standardization, network security, legal framework, research development and other different kind of organizational work. Some key business representatives have been grouped to form a steering committee which develops strategy for realization of the results obtained from the working group [42].

National Initiative: Industrie 4.0

Being a major and leading supplier of industrial equipment's, Industry 4.0 provides even higher opportunities to German companies. Around 15 million jobs are in some form related to manufacturing sector of Germany [43]. This plays a pivotal and decisive role in the international market of German industries. To maintain and grow this leadership strength, Industry 4.0 has been started to adopt at a much faster pace in Germany compared to rest of the countries. Following model presents the fact sheet for German Industry 4.0.

Analysis of German Manufacturing Market

During the research phase approximately 49 projects were reviewed. These projects have been carried out by the German companies under the Plattform Industrie 4.0 program. After completing the review phase the companies were divided into their size, type of Industry and their impact in relation to Industry 4.0.

Graphical analysis was carried out based on following types [43].

Funding Models
- Mixed partnership funding of private with public financing. Offering at a ration of 2/5 or 1/5 respectively

Target Audience
- Educational Institutes, Manufactuers, smal medium enterprises and other policy makers.

Focus Area
- Business model innovation, innovating product and delivery services. Digitalization and coverin ICT markets.

Result Obtained
- Development of advance training, facilities estabished for testing I4.0 compliant mechanism, reduction of industry segregation, movng from research to practical implementation, extensive progress on developing standardization. Work on more than 200 projects so far.

Budget
- EUR 200 million from BMBF and BMWI. This amount is complemented by private companies and industries.

Unique Factors
- There is a fast paced transformation from research to develpment and practical implication. Also strong development of relationship on projects with countries like Italy, France and Japan. Extra help provided to SME, who account for 60% of the manufacturing market in Germany.

Expected Impact
- Developing a reliable network and a standardized framwork. Making Germany's compettive position even stronger in the field of manufacturing.

Grpahical Analysis
- Size of Company
- Type of Industry Segment
- Domain of Customization
- Type of solutions achieved

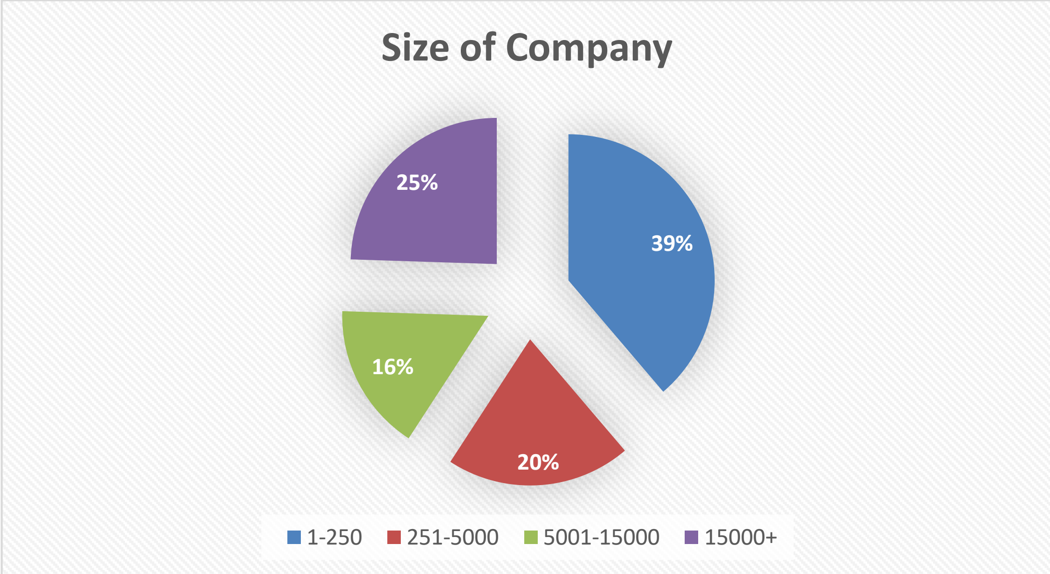


Figure 14 Size of Industry

If we look at the graph above, we notice that majority of the work in Industry 4.0 is processed by small companies where employees are between 1-250 people. Large enterprises with work force over 15000 are also progressing towards modern technology. In total 69% of the projects studied involve these two sectors. They are mainly focused and helped extensively by state institutes on its way to digitalization. Initiatives take by federal states, competence centers for midsize 4.0, associations like BITKOM and ZVEI, the ministries of BMBF, BMWi, the chamber of commerce and other Industry 4.0 platform are offering all types of support, information, advices and workshops to encourage this sector [44].

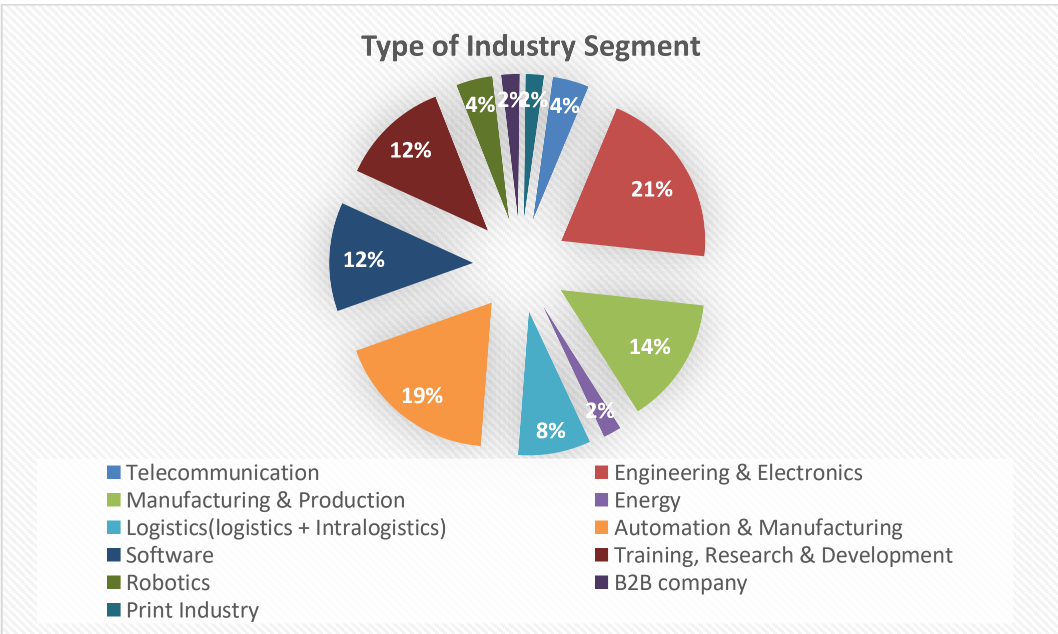


Figure 15 Type of Industry Segment

Majority of projects carried out under industry 4.0 program are related to manufacturing, electronics and automation which altogether accounts for 54%. This shows the commitment of German industries towards achieving greatest excellence and dominance in manufacturing market. At the same time training and educational input is very important. While there are many training workshops, information and test centers are provided through Industry 4.0 program. Many companies have also developed their own set of project specific training and education. These trainings are directed towards educating the staff and increasing their skills for the jobs of future.

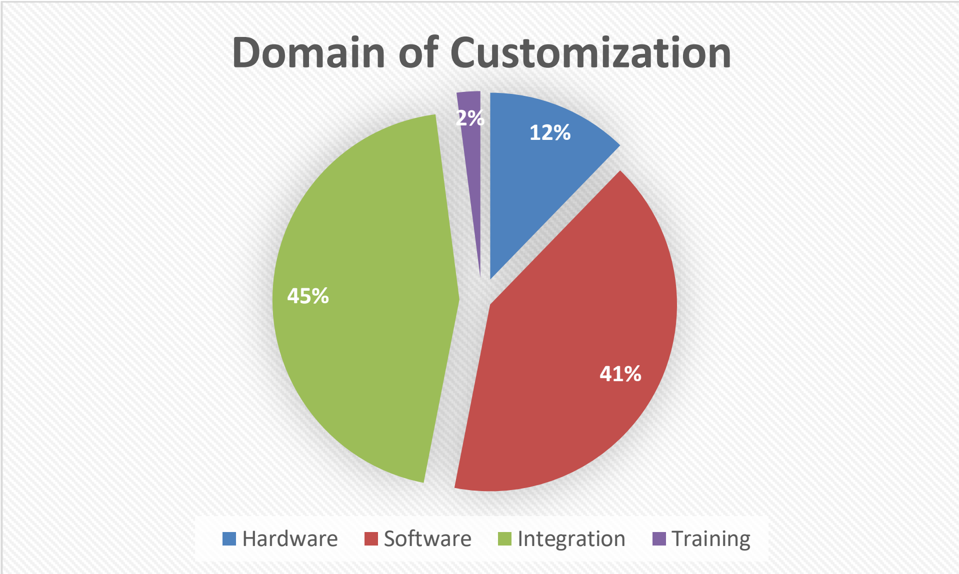


Figure 16 Domain of customization

Solutions for majority projects are related to software and then closely followed by integration (which involves both software and hardware customization) often associated with technologies of automation and a much-preferred approach for industry 4.0 where technology needs to evolve in an integrated way. It is important to note that given the evolving landscape of technology, it is imperative that businesses need to increase their productivity while minimizing cost. Two most important sectors that provide this gain is innovation in the software and automation development [45].

Technological Tools

When a company is going through a transformation process and towards a new technology, there are new ways to quantitatively collect and analyse the data and form a meaningful result. There are wide variety of technological or non-technological tools necessary to quantify the Industry 4.0 and its implementation.

For this research report I identified 11 different technological tools. Some of the tools were subdivided into further elements. Analysis for every project was carried out based on these tools and on what level of technology is each project seeking advancement.

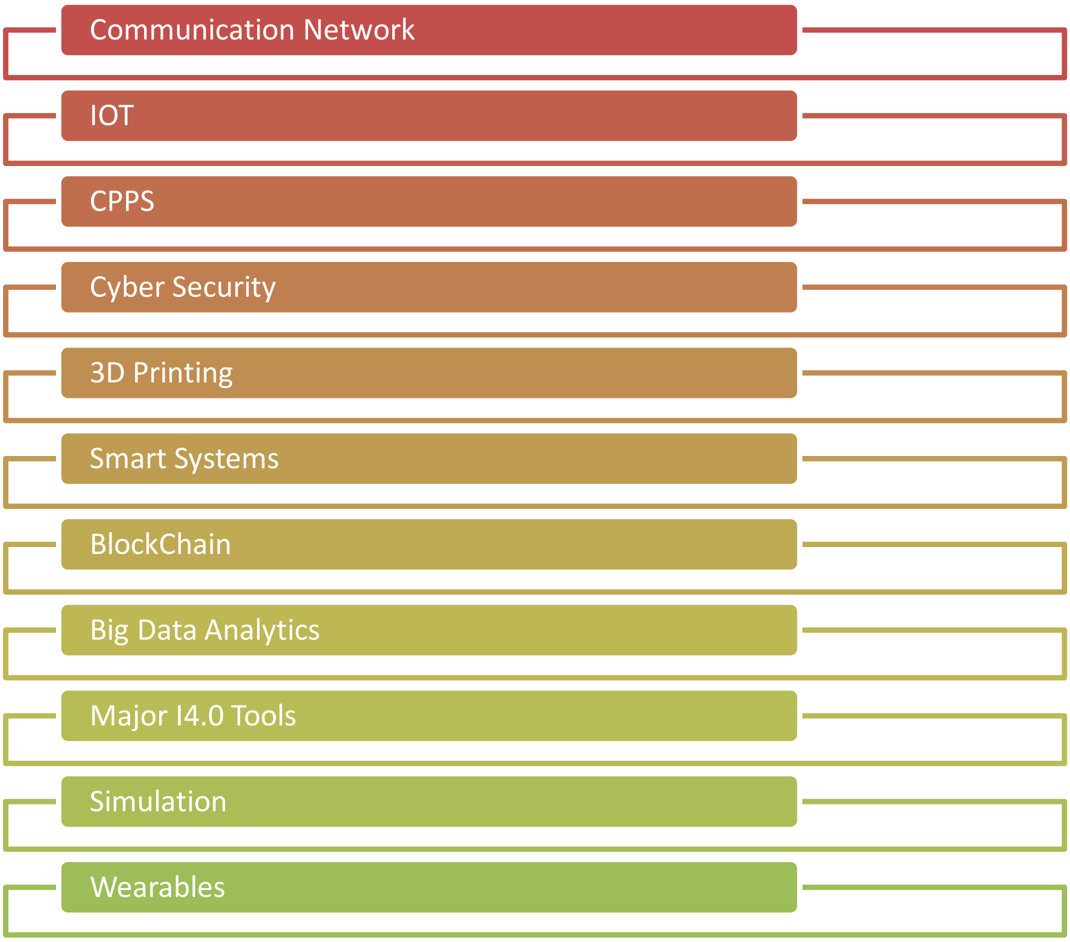


Figure 17 represents the graph for the technological analysis of projects carried out in Germany. Looking at the graph it is evident that the top four tools used by the companies in Germany are IOT, Smart Systems, Big Data and Major I4.0 Tools. These are the most important tools necessary for digitalization. Given the fact that Germany has a well-developed manufacturing environment [46], it would have been predictable to assume that they are leading in the right direction with the right tools.

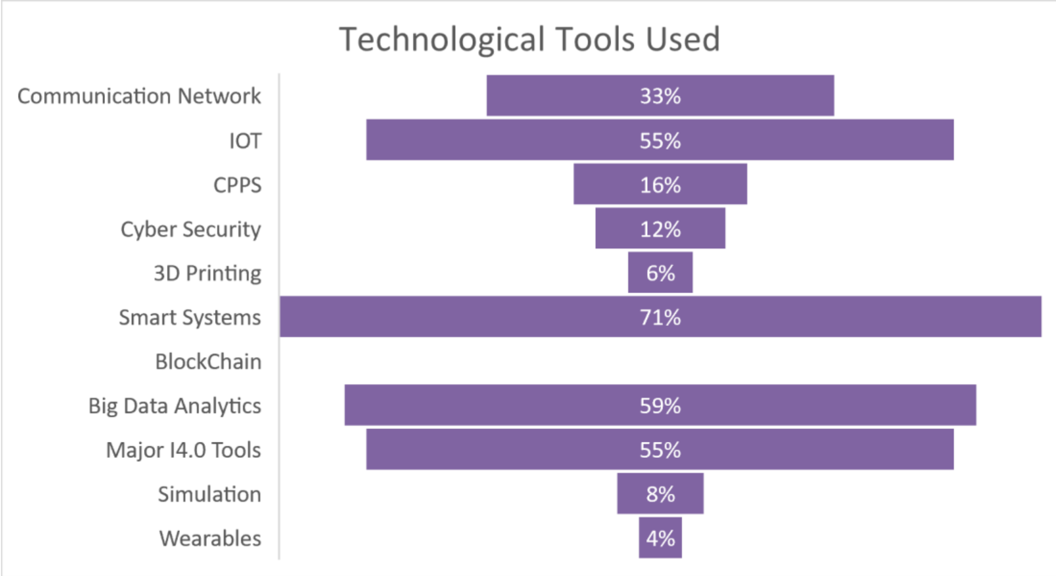


Figure 17 Technological Tools (Germany)

Blockchain is a powerful revolutionary development for the digital era. This technology has been applied around countries such as Estonia with very great and promising results [47]. It was surprising to see none of the projects studied to have an interest in applying blockchain solution. Germany seems to be lagging behind in applying this technology. The government released the Digital Administration 2020 strategy to put measures in order to digitalize and upgrade critical IT infrastructure [48]. Initiatives also include transparency, open data and cybersecurity of intragovernmental communication yet there has been no mentioning of blockchain [49].

If we further look into depth of our technological tools analysis; the smart systems, major I4.0 tools and communication network were broken down into further elements.

Table 4 Breakdown of Technological Tools

Smart Systems	Communication Network	Major I4-.0 Tools
• Smart Grid • Smart Sensor • Smart Technology • Collaborative Machine technology	• Wireless Network • Cloud	• Artificial Intelligence • Virtual/Augmented Reality • Robotics • Automation

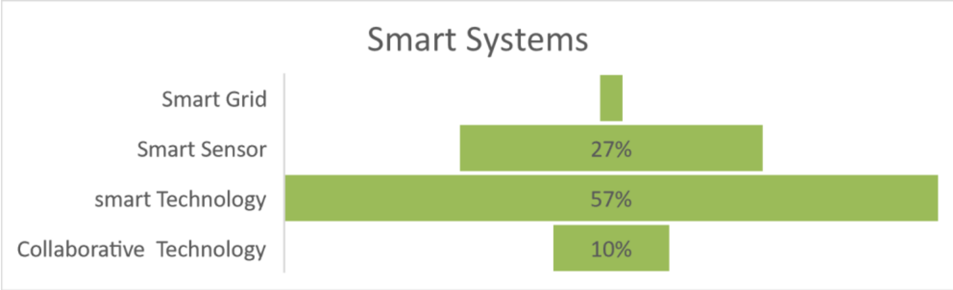


Figure 18 Smart Systems (Germany)

About 71% of projects involved some sort of smart technology this includes sensors, RFID, collaborative technology where a combination of sensors and program allow two machines to work in collaboration.

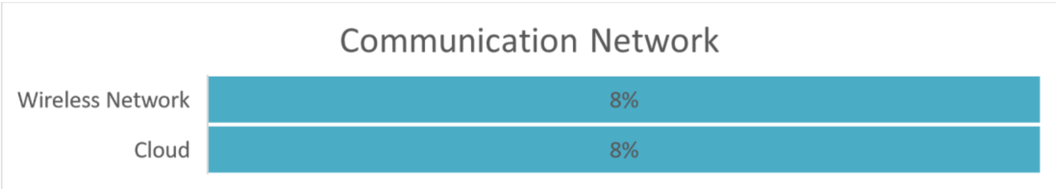


Figure 19 Communication Network (Germany)

31% projects mentioned some sort of communication that was wireless or based over cloud. While cloud is the most efficient and easiest way for IOT devices yet majority companies have concerns due to cybersecurity and are hesitant in exploiting this area more openly.

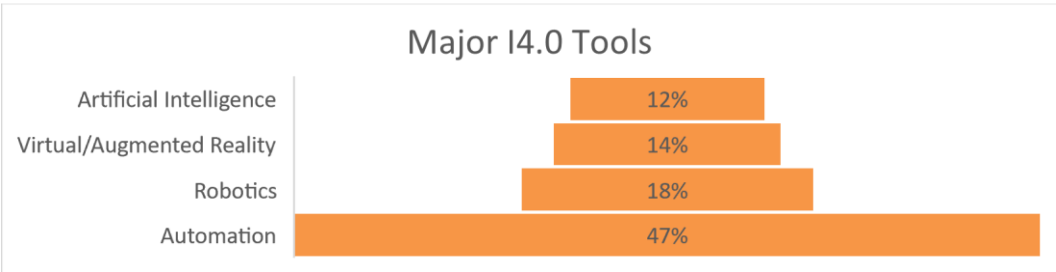


Figure 20 Major I4.0 Tools (Germany)

Major I4.0 tools were used by 55% of the studied projects. While 47% of all projects involve Automation but AI is very limitedly applied to projects with only 12% focused in some ways.

The cutting-edge expertise of today's world where AI is focused and applied to consumer related projects are in hands of few private Chinese and American companies. To name a few they are Alibaba, Amazon and Google. The reason why American and Chinese companies are more open about AI is the fact that their main research centers are mostly based in Silicon Valley and Shenzhen. This gives them an edge over other companies as the data protection and regulatory rules are not so strict and allows them to research more openly towards new solutions. These solutions can later be modified for other regions based on their privacy laws. [50].

In Germany officials are chalking out a final strategy for AI technology, where the final version is expected to include governments pledge to spend around €3 billion on AI technology by 2025 [51]. It is still unclear as to how the spending will be as there is no detailed information so far.

In March 2018, France also unveiled its commitment to spend €1.5 billion over next four years. Given Paris commitment, there has been recent plans to set up joint artificial intelligence centers with Paris, but the idea has again not materialized due to political setback in Germany [50].

Non-Technical Tools

Germany is also focused on educational tools where 16% of the studied project were involved with education. This can be research oriented project, employee training on new technology and related measures to improve educational level within an industry.

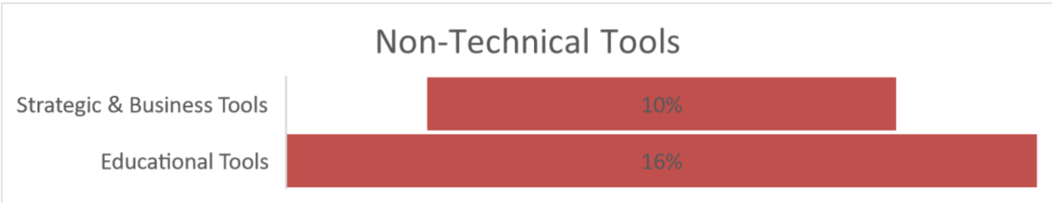


Figure 21 Non-Technical Tools (Germany)

Targets and Expected Outcomes

Any project or business which is initiated needs to be carefully managed in order to ensure the success of the investments and idea that is planned. Targets are set to reach the goal aimed. These target needs to be smart, achievable, realistic and timebound [52].

For this project the most important targets were laid out. These targets are based on what is expected of an Industry 4.0 based environment and how every project response to those targets.

Following are nine different targets. Some of the targets were subdivided into further elements. Analysis for every project was carried out based on these targets and how they stand out in the Industry 4.0 atmosphere.

Figure 22 below represents the graph for the targets of projects carried out in Germany. Looking at the graph it is evident that the top four targets set out by these projects are Operational Target, Communication, Adaptability and workers Safety and Skill Improvement. These are the most important tools necessary for digitalization.

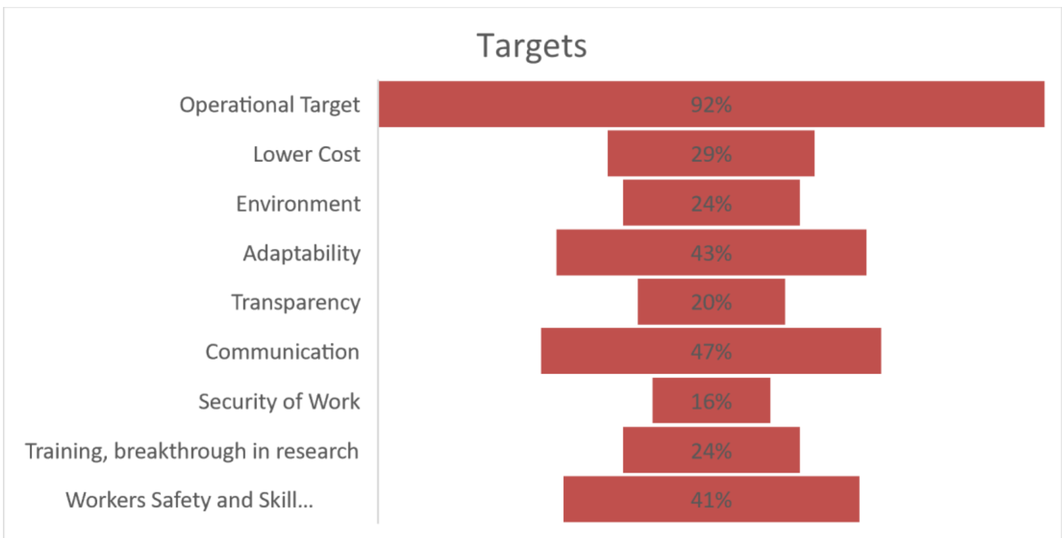


Figure 22 Target (Germany)

Operational Targets is basically a set of minor targets and will be explored below to reveal what kind of operational targets does Germany companies prefer. Adaptability is to be understood here as the ability of a system (e.g. a computer system) to adapt itself efficiently and fast to changed circumstances [53]. Adaptability and efficiency are often seemed as two opposites and one must give up on either to increase the other. In industry 4.0 the idea is to increase efficiency but also make machines adapt to different situations and environment or targets. Communication target involves data sharing which comes from data collection and big data. It also involves decision making which accounts to decision made by the intelligent system itself and communicated as a result. Safety and skill at work is equally important. Moving towards an intelligent industry world where robots are expected to work in collaboration and machine making intelligent decisions, the safety and worker skill is equally important and hence many projects studied involved some form of education of employees to update them on new skills and further having the will to improve in a way where the workers safety was ensured.

As mentioned earlier, some targets are subdivided into elements, this include Operational Target, Environment, Adaptability, and Communication. Following table list down the lower elements.

Table 5 Target divided into sub elements

Operational Target	Environment Control	Adaptability	Communication
•Productivity •Efficiency •Higher Quality •Optimization •Time Saving •Real Time •Reliability & Maintenance Effort	•Smart Energy Consumption •Sustainability	•Flexibility •Customization	•Data Sharing •Decision Making

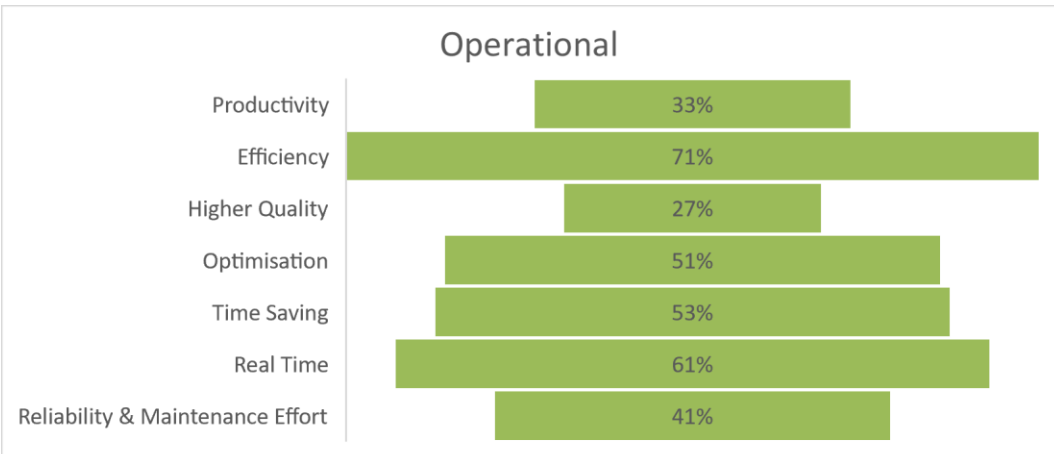


Figure 23 Operational (Germany)

In the figure 23 we see efficiency (71%) and real time control (61%) as the two most important operational targets set by majority projects accounting for.

Higher quality is not a main target. The possible reason could be that German industries already have production outcome based on high quality and the targets from industry 4.0 are mostly based on increasing efficiency, optimization of process and time saving.

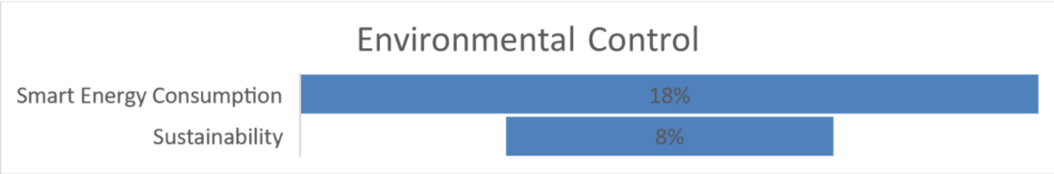


Figure 24 Environmental Control (Germany)

Environment is a bigger concern for today's world. While industrialization and progress is very important for the economic growth of a country and its society development, yet there are manty harmfull effects of it towards environment. Amongst other things industrial process can result in pollution, health issues, climate change, extinction of species and much more [54].

We see here that 18% of the projects are focused on smart energy consumption while just 8% of the projects on sustainability which is quiet low interest.

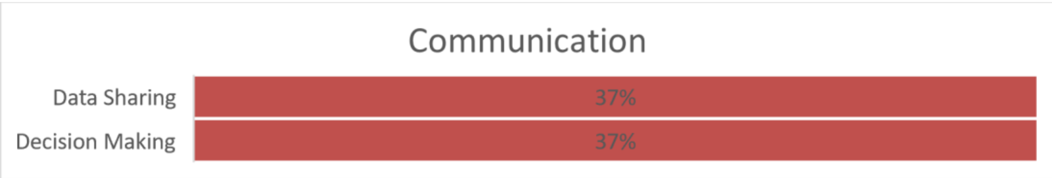


Figure 25 Communication (Germany)

Data sharing and decision-making accounts equally to 37% of the projects. This can be partially associated to data privacy and strong laws because of which communicational targets are not explored at its maximum.

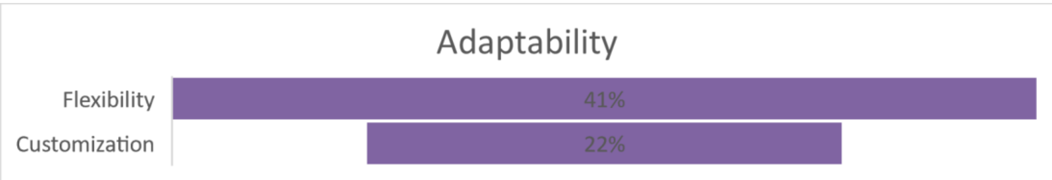


Figure 26 Adaptability (Germany)

As discussed earlier adaptability refers to how a project result/outcome can be applied to multiple areas and not just restricted to one type of work. 41% of the projects are flexible and can be used in multiple environment. 22% of the projects are customizable that is they can possibly be customized according to different needs such as small batch size.

3.4.2 France

France has the third largest economy and second largest population in the EU region [55]. In 2017 the GDP growth was around 1.8% which is expected to decline to 1.6% by 2022. Increase in the physical assets investment which are supported by a strong steady private consumption is a primary reason for driving the economic growth. In July 2017, the Macron led administration devised an economic strategy. This strategy is meant to boost the economic growth, reduce unemployment rate and drive in investments through minimized government spending, tax reforms and easing regulations for the labor market.

The manufacturing sector of France is the eighth largest in the world and third largest in Europe reaching over $250 billion in total Manufacturing Value Added (MVA) in 2016 [56]. This shows the importance of manufacturing sector for French economy equating to 11.3% of the GVA in 2016. In 2016 79.8% of the total manufactured goods were exported [57]. The economic contribution from manufacturing has since dropped and expected to decrease over next 5 years to 9.9% of the GDP [58].

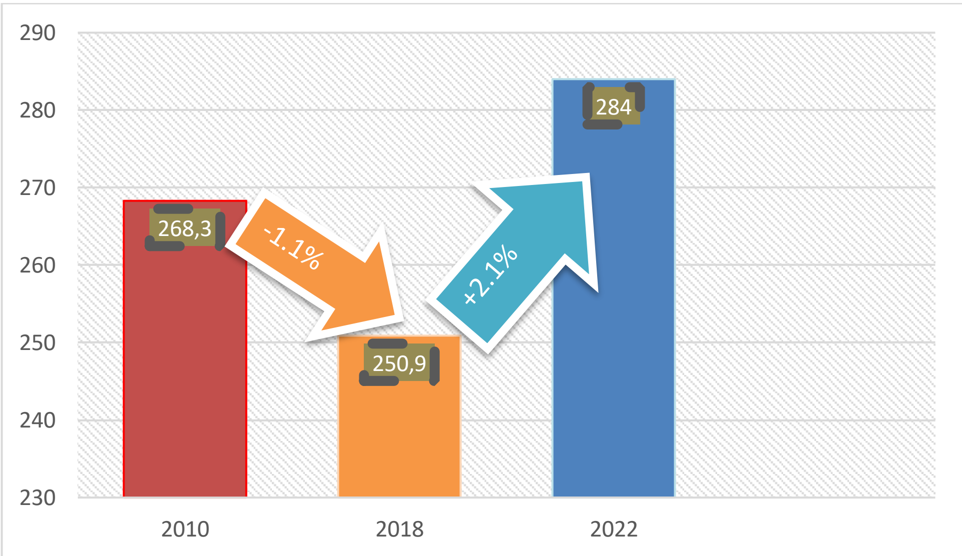


Figure 27 France Manufacturing is expected to recover from downfall trend (MAV 2010-2022) [59]

National Initiative: Industrie du Futur

To support companies from various manufacturing sector and in order to reap the advantages and benefits of Industry 4.0, a program was initiated by the French government in 2015, "Industrie du Futur" (IDF). The program is expected to introduce technological improvements, deploy digital technologies and transform the business models to modernize production practices. Through such reforms it is expected that MVA will increase to 2.1% between 2016-2022 [59].

IDF had developed targeted priority markets and is comprised of five pillars [60]:

1. Cutting-edge technologies,

2. Business transformation,
3. Training,
4. International cooperation and,
5. Promoting IDF.

The program also has support of other stakeholders such as industry itself, researchers, trade unions in order to form a common ground and establish a proper network structure that can manage and support the digital transformation.

Despite the strengths that France have due to its innovation-based ecosystem and digitalized industries, their companies still face many challenges. These challenges are varied related to making the process more connected, responding to customers' requirements and ensuring long-term competitiveness with international market. This is a reason why France needs to transform its business model and strategies and improve its production technology.

The following figure represents the main feature of the French program.

Funding Models	• Mixing public funding instruments as loans and tax aid with private investments in R&D and production lines; a private leverage effect of five times is expected
Target Audience	• French industry and production base and in particular SMEs and mid-caps
Focus Area	• Supporting the use of digital technologies, modernising production tools and transforming business models
Result Obtained	• Provided loans to over 800 companies, supported 3400 companies with a diagnosis for modernising production, identified over 300 experts and involved 18 regions
Budget	• Approx. 10 billion from public sources, including IftF funding from 2017 onwards, supported by private funding
Unique Factors	• Composition of widely covering financial instruments and calls and role of authorities and platforms at the regional level to ensure implementation
Expected Impact	• New cooperation, funding and support activities will promote excellence in fundamental research, technology transfer and industrial innovation

Implementation Plan: Using Five Priority Pillars

1. **Technological Offerings:** It focuses on next gen technology. The purpose of this activity is to support companies with funds for research, different type of subsidies and loans. Other areas of interest includes development of a network of different platforms which could be used for testing new technologies with main emphasis on regional platforms that help local companies to test out their technology.

2. **Financial and Personalized Support:** Financial and personalized support is provided to companies so that they could invest in renewed production processes and engage in different projects.

3. **Training and Upskilling of Workforce:** The idea to achieve is through joint and bilateral effort with different unions and developing training programs and a curricula.

4. **International Cooperation:** In todays connected world, cooperation is very important otherwise a country can be left isolated in the world community. To keep up with a strong positive and upward growth the target is to develop standards and alliances also with the international partners. A strong cooperation is developed with Germany (Industrie 4.0 project) in order to standardize and work on projects mutually benefiting the progress. At the same time France is also taking interest on EU level and in the Horizon 2020 program.

5. **Promoting IDF:** This is achieved by launching flagship projects, International trade fairs and branding through, "Creative France Industry" [60].

In order to further promote the manufacturing sector export and to let the market share grow globally, the Alliance Industrie du Futur and supporting French groups launched a new initiative, "French Fab" which promotes *Made in France* as its symbol. The attempt is focused on medium sized firms which is the base strength of French manufacturing. The aim is to strengthen the economy making it more competitive [59].

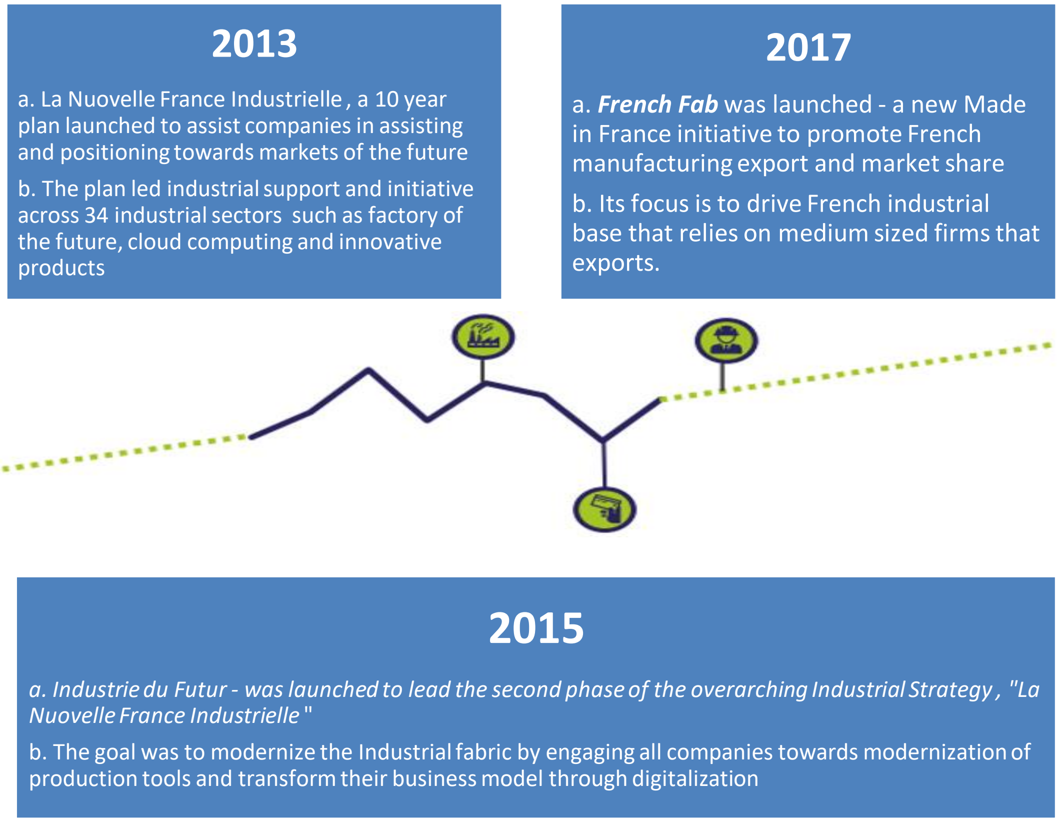


Figure 28 Government efforts over the years for French Industrial progress [59]

The overall aim of IDF is to strengthen the manufacturing industry through new and emerging technologies which include AI, IoT, Additive manufacturing techniques, Smart production and new materials. Also, to develop a strong collaboration and combine the services and production into one system hence providing full solution from design, production process and logistics to post-sale services.

Future Perspective

The future of the manufacturing industry of France can be shaped in two ways:

1. By creating a strong attractive environment for industry and other stakeholders to invest in projects and adopt Industry 4.0 technologies. For this purpose, Industrie du Futur needs to provide a clear and standardized way forward in implementation, legal support and help in developing framework.
2. A need to develop and bring up the startups and SMEs towards growth and exploit their innovative skills on a larger scale which can prove more powerful for quick growth in the international arena.

Analysis of French Manufacturing Market

During the research phase approximately 32 projects were reviewed. These projects have been carried out by the French companies under the Alliance industrie du futur. Graphical analysis was also carried out for France. France and onward, this thesis only detail about the results and discussion instead of explanation the graphical purpose which was already explained in the part related to Germany.

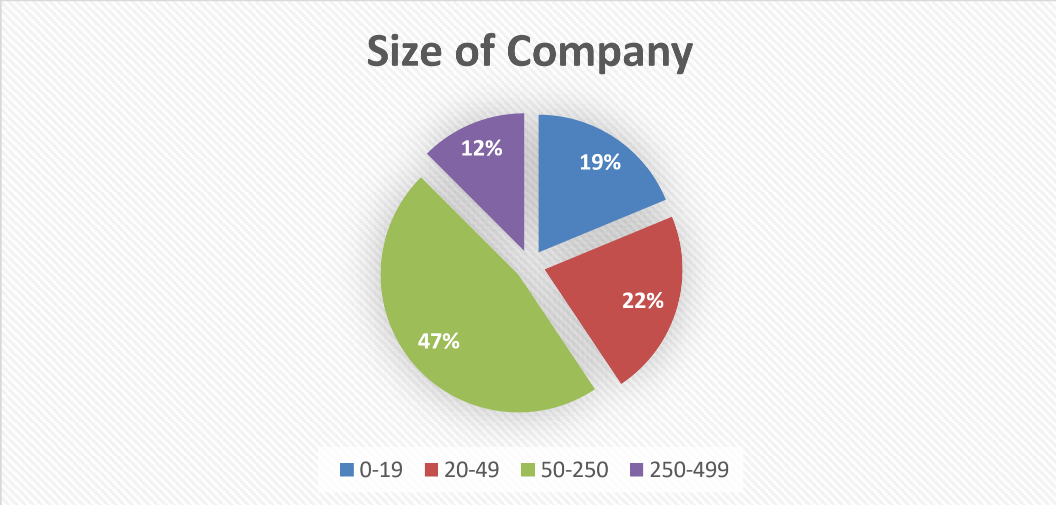


Figure 29 Size of Industry

If we look at the graph in figure 29, we notice that majority of the work in Industry 4.0 is processed by medium sized companies where employees are between 50-250 people. Large enterprises have a very less share in investing towards high tech industry in France accounting for only 12% of the projects that were studied. A possible reason could be the fact that big companies don't feel the threat of competition and are largely enjoying due to their dominant position. Another reason is a threat that large enterprises feel with new technology. They prefer to adopt a technology when mature rather than heavily investing in something very new (this is a result of pessimistic view).

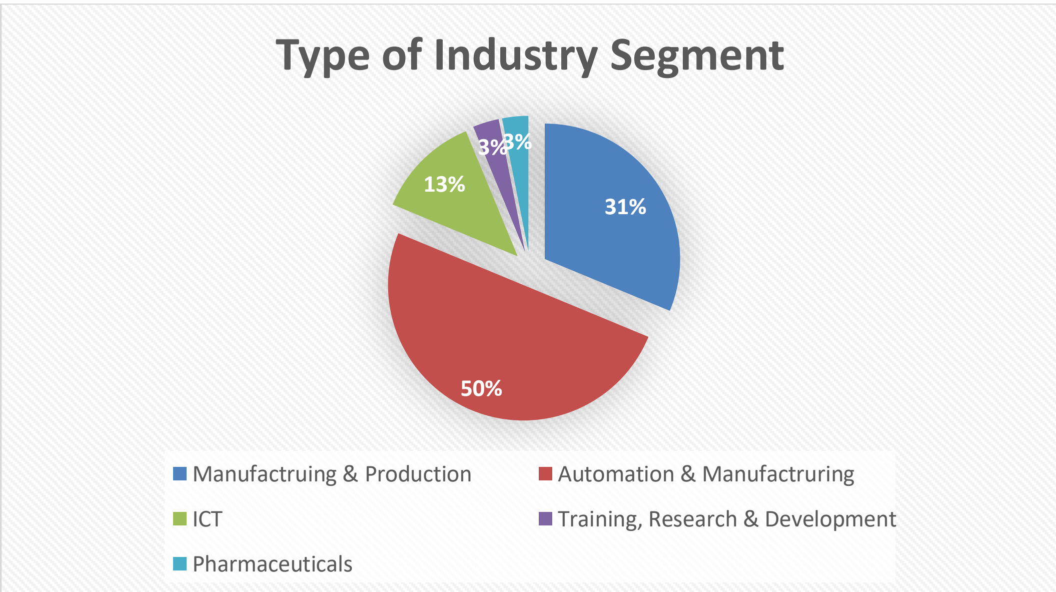


Figure 30 Type of Industry Segment

Majority of projects carried out under Industrie du Futur program are related to manufacturing, and automation which altogether accounts for 81%. This shows the commitment of French industries towards achieving greatest excellence and dominance in manufacturing market which is also a result of a lot of projects recently initiated by the country. Training and educational activities account for almost 3% which is alarmingly low. It is expected that this sector will rise over the next few years due to a more serious program launched by French administration as discussed earlier; French Fab [61].

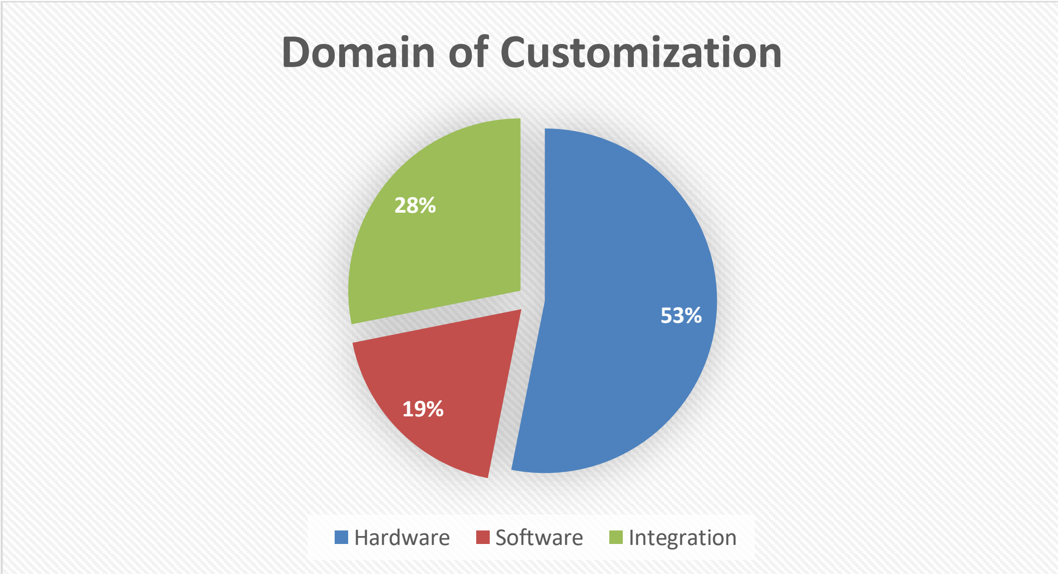


Figure 31 Domain of customization

Majority of project studied were related to hardware customization accounting for 53%. It is quite different to Germany where focus lies on integration and software.

Technological Tools

The same technological tools were used to identify where the French companies are investing. Figure 32 represents the graph for the technological analysis of projects carried out in France. Looking at the graph it is evident that the top two tools used by the companies in France are major I4.0 tools and smart systems. IOT was not a major investment made under any of the project studied with just 3% overall interest. There has also been no specific project carried out in line with CPPS which is one of the most important aspects of Industry 4.0 as studied in chapter 2.

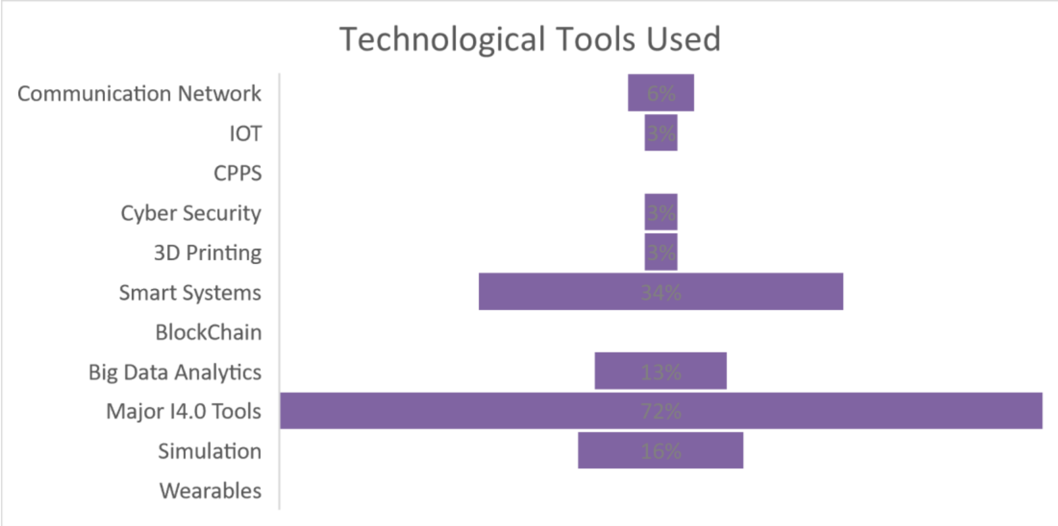


Figure 32 Technological Tools (France)

Blockchain is a powerful revolutionary development for the digital era which has been overlooked by the French companies. The main reason is the France failure to materialize government plans and to make ends meet despite continuous new effort and plans. This has caused many startups and investors to lose a confidence in the government strategy and vision. In March 2018, the financial administration announced a plan to regulate cryptocurrency market but after all these months the bill is not even close to being passed [62]. If passed such a bill would provide friendly and efficient system of regulation for the startups. The government inability to work on its promise can continuously damage the interest of companies particularly large enterprises.

If we further look into depth of our technological tools analysis; the smart systems, Major I4.0 Tools and communication network, they are broken down into small elements.

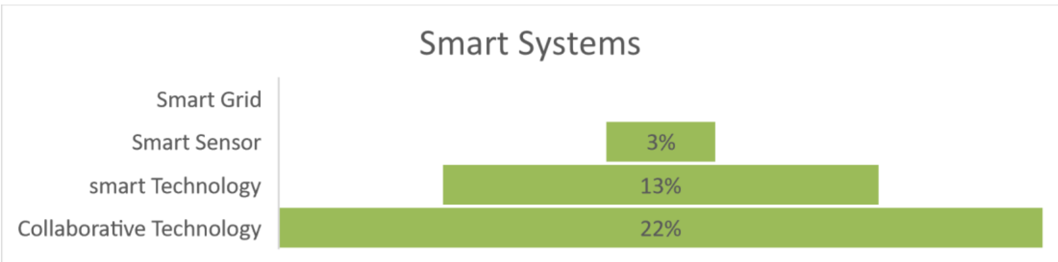


Figure 33 Smart Systems (France)

In France the focus remains on smart and collaborative technology with additive manufacturing is one type of collaborative technology in use.

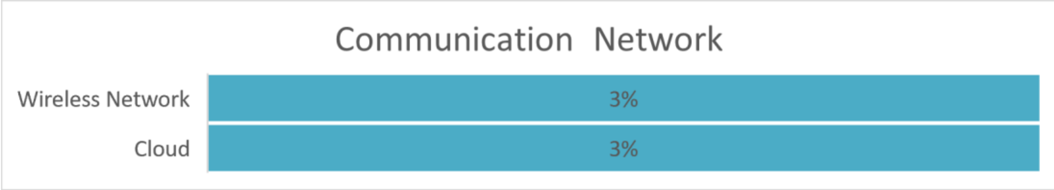


Figure 34 Communication Network (France)

Very limited knowledge was available regarding communication network with only 3% of projects accounting for it.

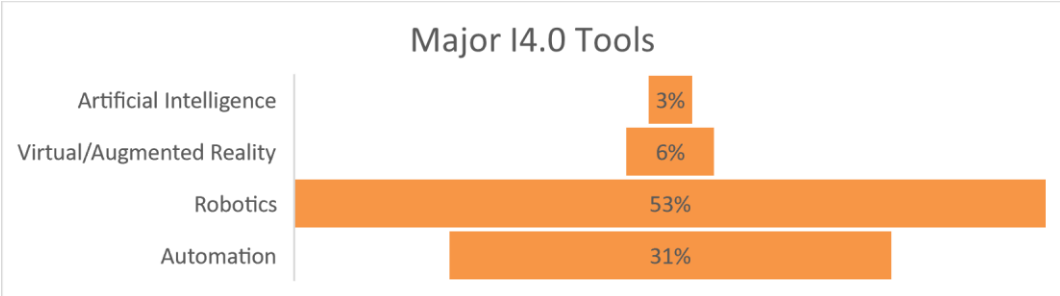


Figure 35 Major I4.0 Tools (France)

Major I4.0 tools were used by 72% of the studied projects. 53% of all the projects account for robotics while 31% to Automation which is a point of great attention. There was almost no interest found in any project related to AI but French administration had very recently started showing interest in this field. In March 2018 a plan was revealed by France to spend around €1.5 billion over next four years. Under this plan there is also an agreement with Germany to form a joint AI center [50].

Non-Technical Tools

France is more focused on strategic and business tools where 36% of the studied project were involved.

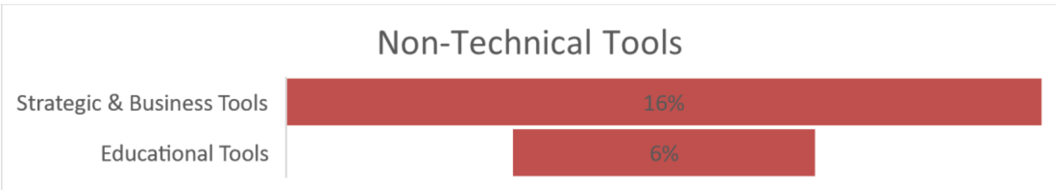


Figure 36 Non-Technical Tools (France)

Targets and Expected Outcomes

Following are the outcomes of nine different targets for projects studied. It is evident that the top two targets set out by these projects are Operational Target, and workers safety and skills development. Other than that, lowering cost and adaptability were also the next important targets.

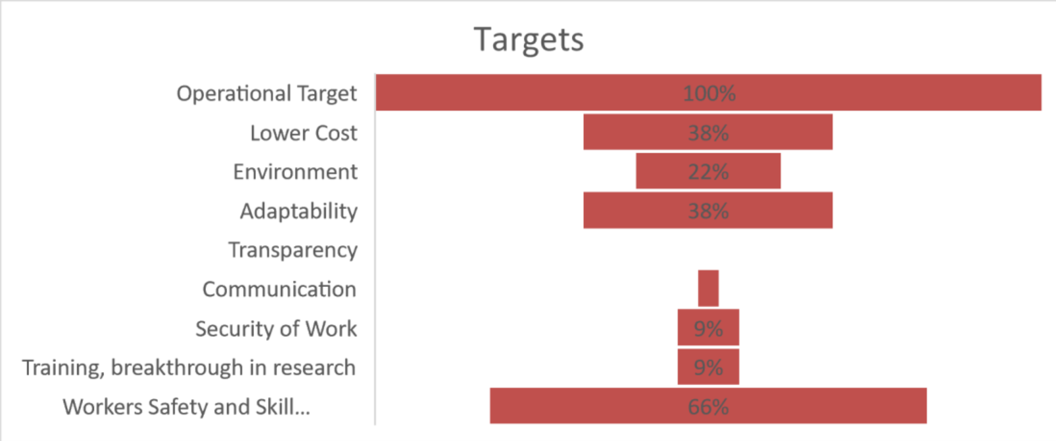


Figure 37 Targets (France)

As mentioned earlier, some targets are subdivided into elements, this include operational target, environmental control, adaptability, and communication. Following figures list down the lower elements.

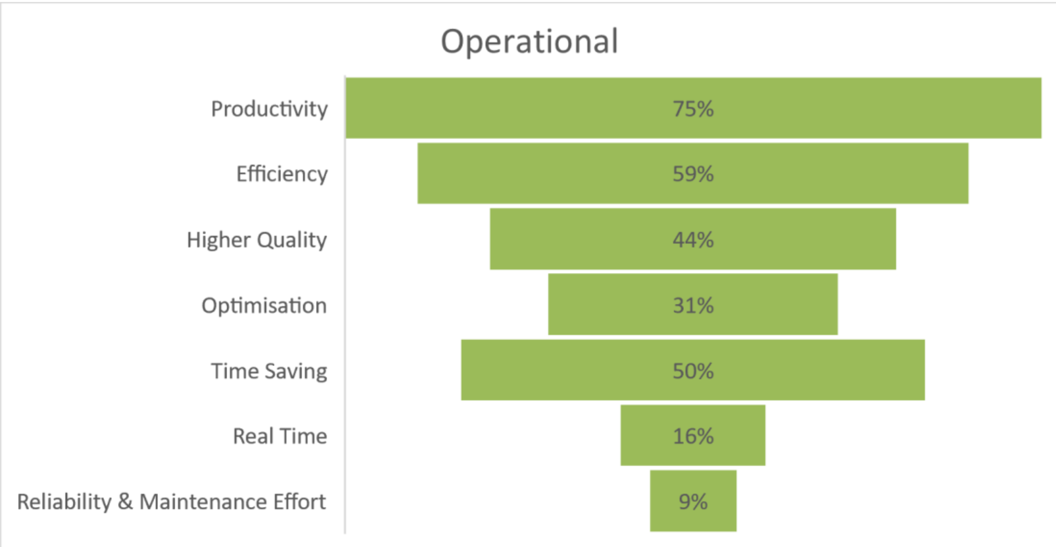


Figure 38 Operational (France)

In the figure above, we see Productivity (71%), efficiency (59%) and time saving (50%) are three most important operational targets set by majority projects. Time saving automatically leads to higher productivity.

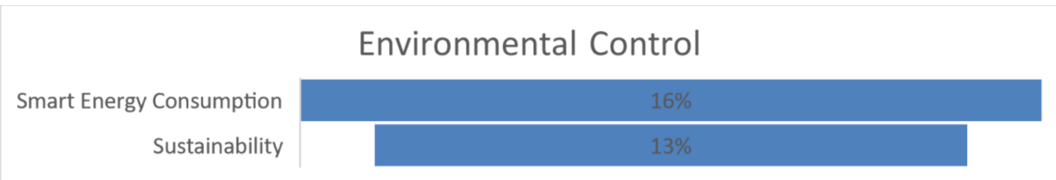


Figure 39 Environmental Control (France)

While concern for environment is very important yet there has been no prominent interest here with only 16% projects caring about it.

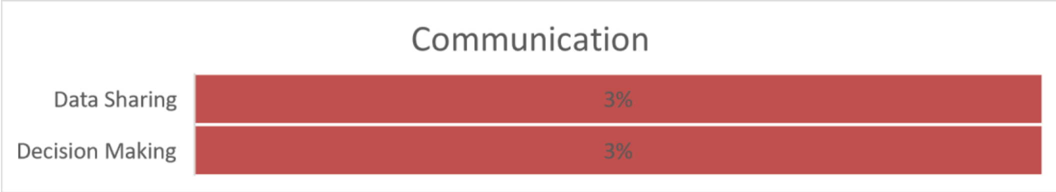


Figure 40 Communication (France)

Data sharing and decision-making accounts equally to 3% of the projects. This shows a very low level of interest but also the fact that due to strong laws and very limited government interest companies are not willing to adopt or work on technology related to data.

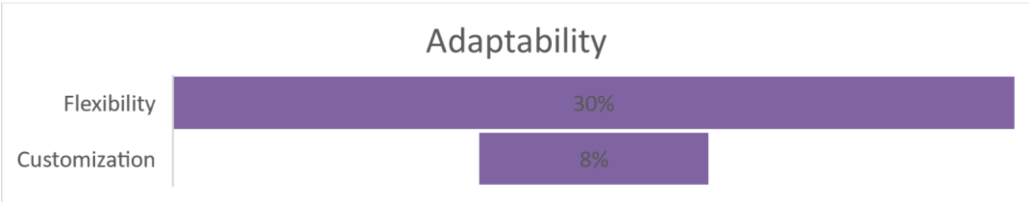


Figure 41 Adaptability (France)

30% of the projects are flexible enough to be adaptable which indeed is a good number.

3.4.3 Spain

Manufacturing industrial sector of Spain provides 13% of added value and employs 11% of the working population hence having a major impact on the economy [63]. The country stands as fifth largest economy in the EU zone and thirteenth around the world [64]. Highest production level was achieved in March 2017 compared to 2008 and the employment has been constantly rising with record 37 successive months in October 2017 [65]. There is growth and continuous expansion is observed in the manufacturing industry.

According to a study conducted by The European Digital Economy & Society Index (DESI), Spain ranks 14th (in 2017), making it lag behind in the race of digital transformation, keeping it a little behind the average of EU on some aspects as depicted in figure 42 [66].

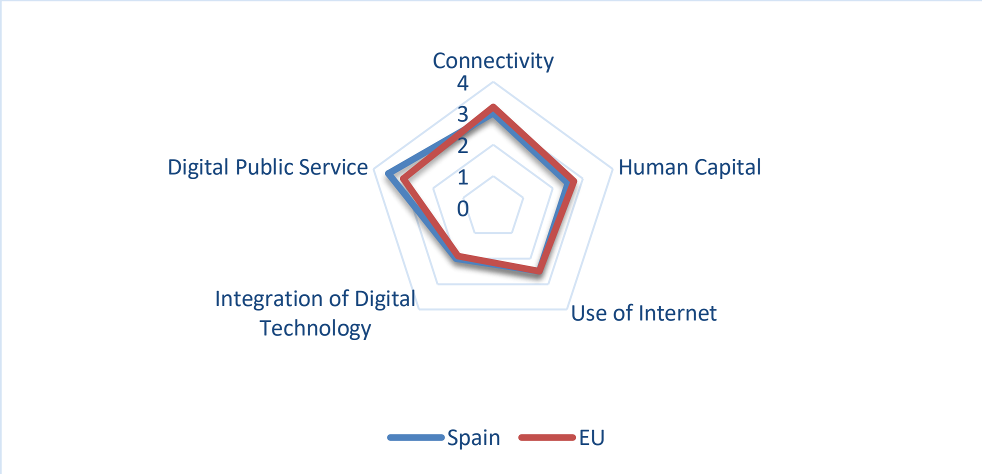


Figure 42 Digital Economy and Society Index (DESI), data taken from European Commission

Considering this, the Ministry of Industry (MINECO) launched an initiative which is meant to increase the GDP contribution from Industrial output by €120,000 million until 2025 using digital transformation [63]. Digital transformation is a priority for the Spanish industry and many stakeholders are working together to push for a common goal towards Industry 4.0 making an urgency in the market.

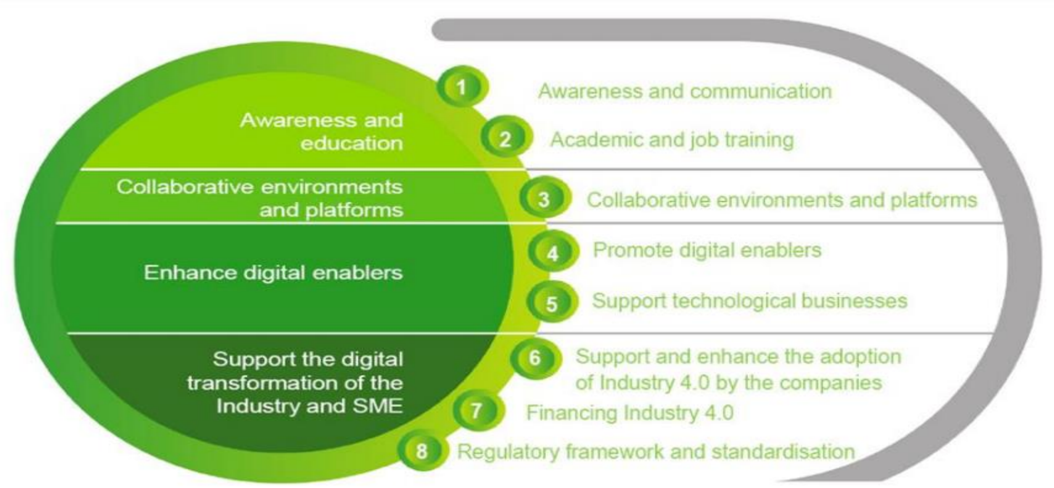


Figure 43 Eight points agenda

National Initiative: Connected Industry 4.0

Connected Industry 4.0 (CI4) is the main initiative and part of the Spanish Digital Agenda which is meant to strengthen the industrial sector. The General Secretary of Industry and SME under the Ministry of Economy Industry and Competitiveness launched this initiative in 2015 [67]. This initiative has since then defined a model for governance which resulted in creation of several departments under a single Secretariat.

The aim of this initiative is the introduction of digital technology in manufacturing industries to enhance them and increase their competitiveness globally while keeping in line the Industry 4.0 model. This means a more collaborative and connected production process where supply chains are integrated, and digital channels of distribution are emerged with eye on customer services.

CI4 is based on four focused areas

1. **Digital Industrial Platforms and R&I actions:** Main goal of this initiative is to create an environment and marketplace where suppliers with industry 4.0 compliant solutions integrate with industrial customers who can use these services and products for their processes. At the same time increase the awareness of Industry 4.0 program and its benefits. Digital Platforms are planned for both national and regional level. Role of such platform is indeed to develop a collaborative environment for practical implementation. National Committee on Industry 4.0 has been set up by the Spanish Association on Information and Communication Technologies and Electronics (AMETIC) which brings together approximately 83 companies working on various committees. These companies are working on white paper documentation and collaboration of different projects in areas of (1) Talent 4.0, (2) Co-Creation Industrial Fabric (3) Technology Enablers (4) Benchmark and Dissemination. One of the most important point to mention is the fact that Spain has the largest optic fibre deployments in whole Europe thus making highspeed broadband internet access to the industries very easy. At the same time the initiative has reserved 100M€ to continuously develop the national broadband plan [65].

2. **Standardization actions, regulation and testbeds:** Standardization is another key pillar of the CI4 initiative which was set up in July 2017. An Executive Committee was set up for the Standardization Working Group. The Spanish Standardization Association, Mondragon Corporation and the UNE will be coordinating this committee. Many universities, companies and industrial associations are included in this group [65].

3. **Digital Innovation Hubs actions:** This strategic pillar of CI4 has supported development of more than 98 Innovative Enterprises with investment leading to approximately €11 million annually. In May 2017 DIH Working Group was kicked off. A tool developed under the CI4 initiative called HADA was made available to this program. This tool performs self-assessment for Industry 4.0 maturity. In September 2017 another initiative was established called ACTIVA which is meant to support the Spanish industry in developing plan for digital transformation. An important €28 million in direct investment that needs to be mentioned is the advanced 3D printing hub in Catalonia region as a result of collaboration of different research centers in the region and involvement of major companies such as HP, Renishaw and RICOH [67].

4. **Skills development:** Skill development is a central element for CI4. It is supported through digital training programs which are managed by Red.es. An yearly budget of €45 million is supporting the digital skills program. This program is a lifelong support for complete educational and training starting from early years of vocational training leading to youth employment and further continuous training. Entrepreneurial aspects of the skills are also developed through this program [67].

Table 6 Spanish National Strategy Overview

Action and Education	Strategic Areas	Objectives
Awareness & education	*Amareness creation and communication* *Academic and job creation*	Guarantee knowledge of I4.0, its enablers and its benefit Ensure the availability of I4.0 skills
Encourage multidisciplinary collaboration	Collaborative environments and platforms	Foster collaboration by promoting environments and platforms that are adapted to industry and focused on 4.0 technology
Enhance digital Enablers	Promote digital enablers Support technological businesses	Boost R&D&I in I4.0 technologies Boost the busines development of technology providers
Support digital transformation of the Industry and SME strategic areas	Supporty to Industry's adoption of I4.0 Regulatory framework and standardization I4.0 projects	Support and enhance the adoption of I4.0 by the companies Regulatory framework and standarization Financing I4.0

As part of the national strategy there is no solid policy related to tax incentives, yet there is some dedicated program such as soft loans around €15 million yearly which are used for the development of new digitalized businesses following the guidelines of Spanish Digital Plan [65].

The figure below represents the key analysis of Connected Industry 4.0 [67]

Funding Models	• Public-private partnerships. Loan and direct aid based system to ensure participation of the private sector with expected leverage effect of 1:2
Target Audience	• Enterprises with industrial activity, in particular SMEs and micro-enterprises.
Focus Area	• Focus on digital enablers, in particular intra and inter-enterprise enablers, with impact areas in employment and competitiveness settings
Result Obtained	• Set-up of innovation and research programme in June 2016 and pilot of enterprise support programme
Budget	• €97.5 million connected industry project calls for 2016; related programmes provide additional €68 million (loans and direct aid) for ICT companies and €10 million for innovative clusters
Unique Factors	• Strong SME and micro-enterprise and digital transformation focus through specific project calls giving loans to industrial enterprises and through a mentoring programme to guide the implementation of 4.0 for industrial enterprises
Expected Impact	• Development of local supply of digital solutions and elaboration of differential • competitive levers to boost industry and exports

There seems a strong engagement by government, industrial ministries, agencies and other key stakeholders to transform the Spanish manufacturing industry towards digitalization. It is expected that the economy will grow as planned if the agenda is worked out with full commitment.

Analysis of Spanish Manufacturing Market

During the research phase approximately 37 projects were reviewed. These projects have been carried out by different Spanish companies or research institutes. Graphical analysis was also carried out for these sectors.

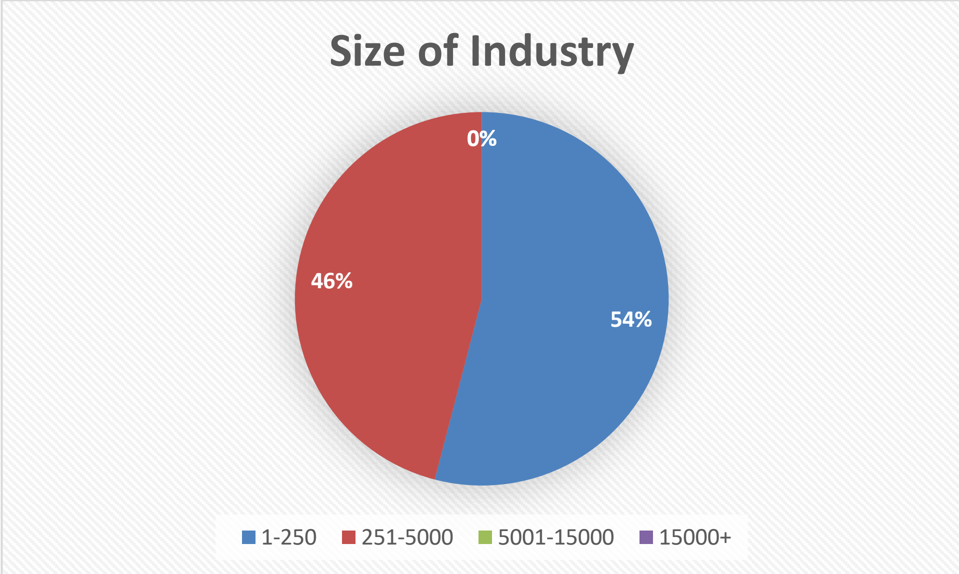


Figure 44 Size of Industry

If we look at the graph above, we notice that majority of the work in Industry 4.0 is processed by small sized companies where employees are between 1-250 people. There was almost no knowledge available regarding any major investment or project by large corporations. A paper was published by National Bureau of Economic Research which argues that due to majority of economic power lying in the hand of few big corporations and in some cases to a point where these companies enjoy a near monopoly could explain this trend of no. Big firms are not concerned about their competitors and hence simply stay away from investing [68].

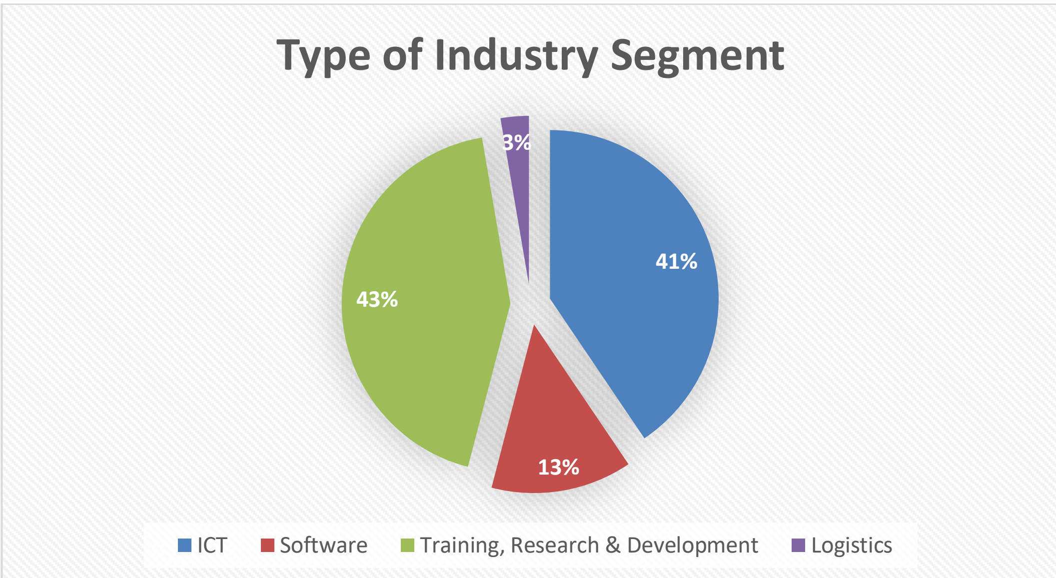


Figure 45 Type of Industry Segment

Majority of projects carried out under industry 4.0 program are related to Training, Research & Development accounting for 43% of all the projects, followed closely is 41% interest from ICT projects. This shows that Spanish companies (majority of startups, Small enterprises) are really putting effort into R&D and ICT based projects which is a very positive trend towards digitalization.

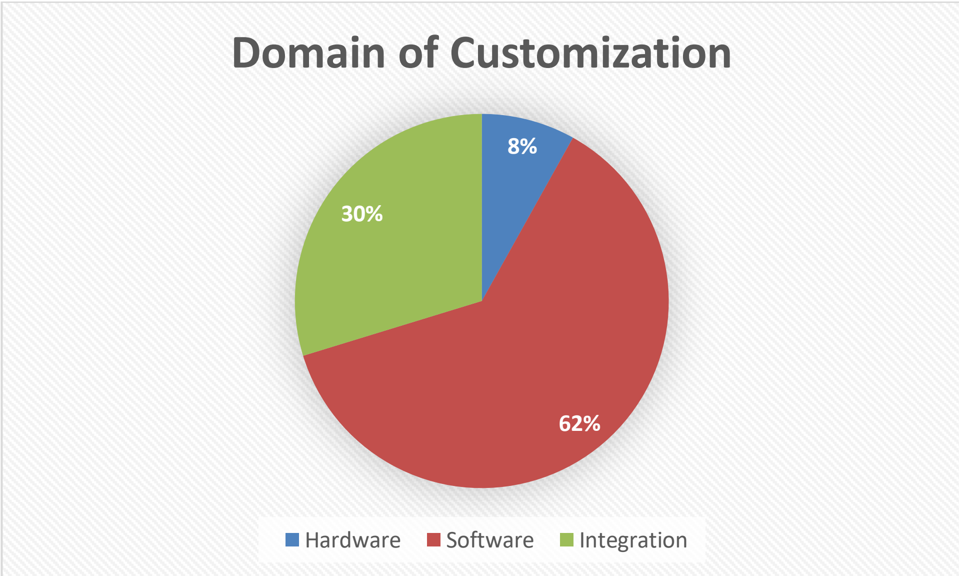


Figure 46 Domain of customization

Many project studied were related to software customization accounting for 62%. It is quite different to France where focus lies on hardware. Given the project interests mostly in R&D and ICT, it is expected that the customization is more directed towards software. Software technology is becoming very critical for a company's performance [69]. Software technology provides the basic foundation for a company to use its data more effectively and benefit from the power of digitalization [70]. Any company that want to compete today on a global level need to have a mature level of software customization within their business structure.

Technological Tools

Technological tools were used in order to measure the progress that each project was aiming at. Figure 47 represents the graph for the technological analysis of projects carried out in Spain. Looking at the graph it is evident that the top two tools used by the companies in Spain are major I4.0 tools (49%) and big data analytics (38%).

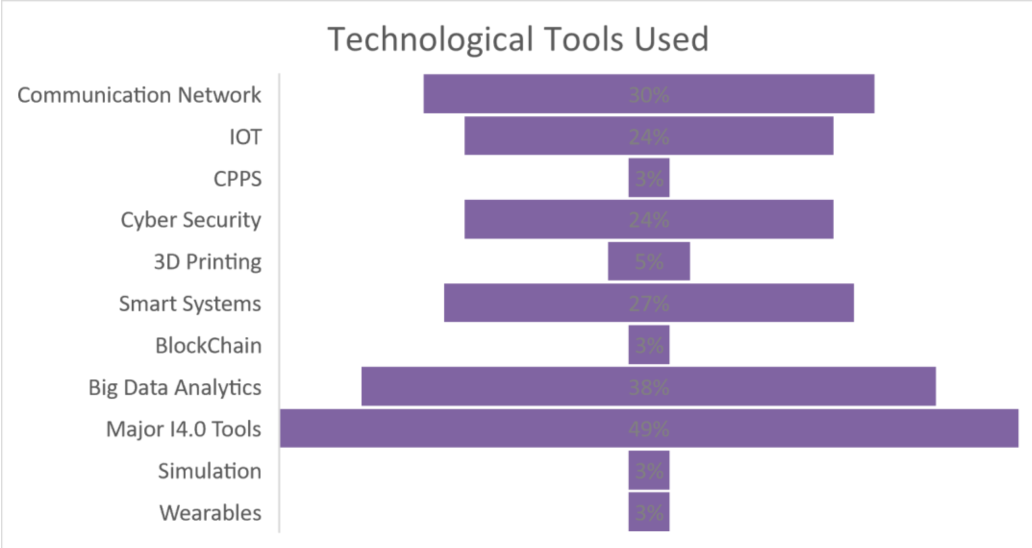


Figure 47 Technological Tools (Spain)

Overall considering the recent progress by Spain towards digitalization, it seems that the country is moving towards an uptrend. They are heavily investing in projects related to R&D by companies like EUROCAT who has initiated many different projects so far. Other projects are carried out by university research labs. Small companies and startups are more focused on ICT based projects and are slowly changing the scene of Spanish industries.

If we further look in depth of our technological tools analysis; the smart systems, major I4.0 tools, and communication network is broken down into small elements.

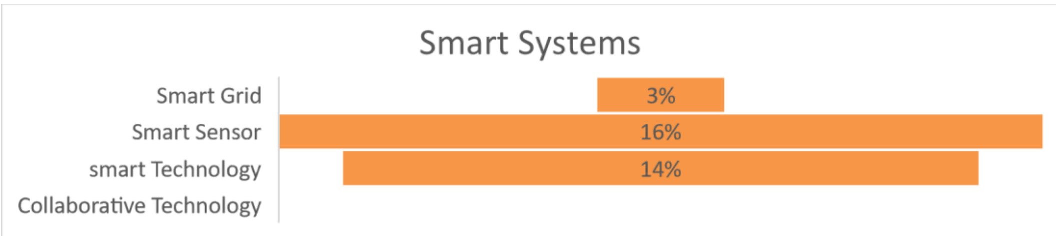


Figure 48 Smart Systems (Spain)

In Spain the focus remains on Smart Sensors and Smart technology with 16% and 14% projects focused on using them respectively.

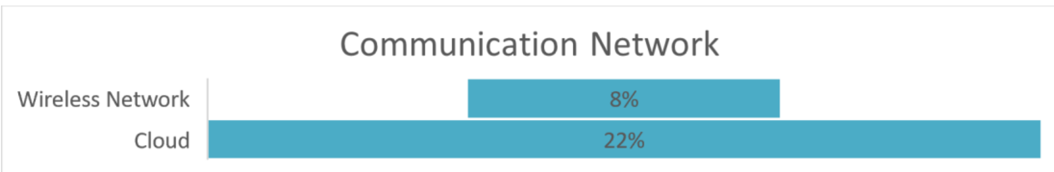


Figure 49 Communication Network (Spain)

It was yet interesting to see that 22% of the projects involved the use of cloud technology which is a plus point and a major tool towards digitalization.

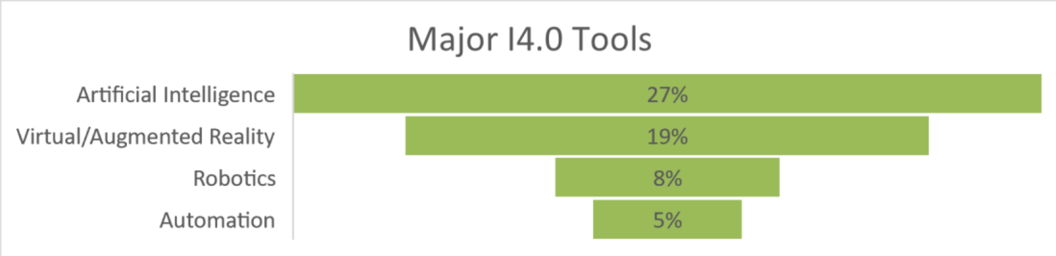


Figure 50 Major I4.0 Tools (Spain)

Major I4.0 tools were used by 49% of the studied projects. 27% of all the projects account for AI while 19% to virtual reality which is quite different to what we studied in relation to Germany and France where the focused tools were robotics & automation. According to data collected by Randstad, majority of the workers (63%) in Spain believe that AI can bring a positive development towards their skills and employment [71]. At the same time 88% of the professionals are interested in going through digital training to improve and increase their employability.

Non-Technical Tools

Spain is more focused on Educational Tools where 19% of the studied project were involved. R&D based projects mostly involve educational outcomes that are further applied on different research.

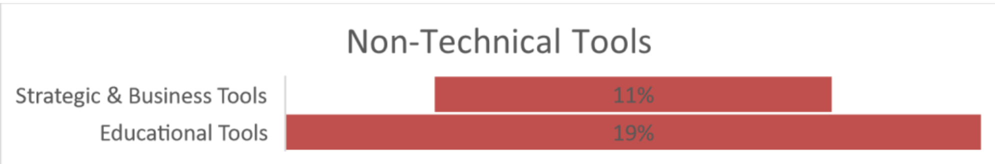


Figure 51 Non-Technical Tools (Spain)

Targets and Expected Outcomes

Following are the outcomes of nine different targets for projects studied. It is evident that the top two targets set out by these projects are operational target, and communication.

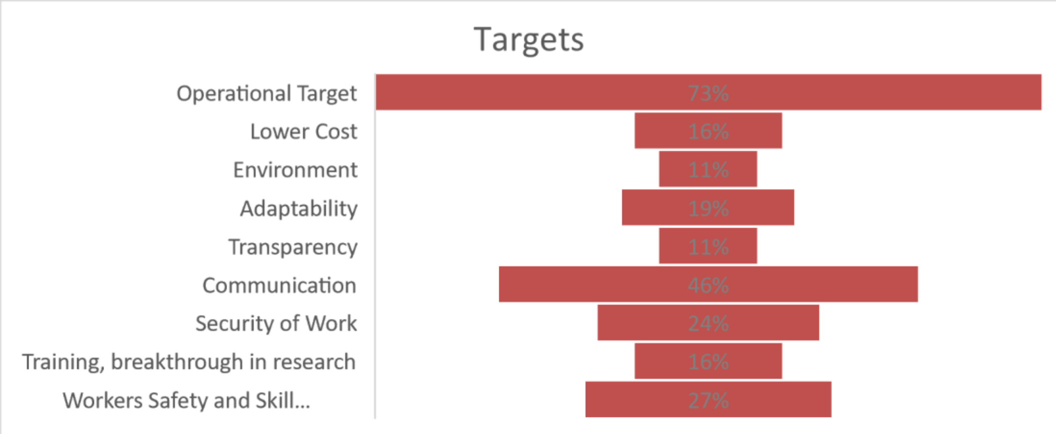


Figure 52 Target (Spain)

As mentioned earlier, some targets are subdivided into elements, this include operational target, environment target, adaptability, and communication.

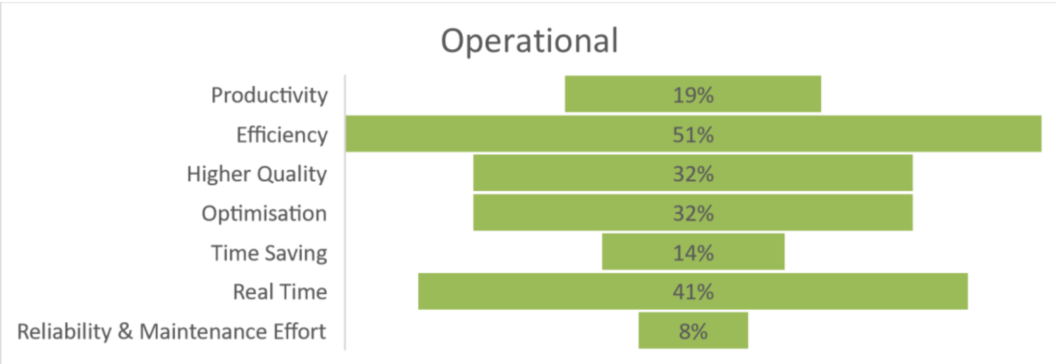


Figure 53 Operational (Spain)

In the figure 53, we see efficiency (51%) and real time (41%) as two most important operational targets set by majority projects. The reason for productivity as not being a major target can be associated with the fact that majority projects studied are R&D with focus on specific results instead of being implemented directly by industries for increasing productivity.

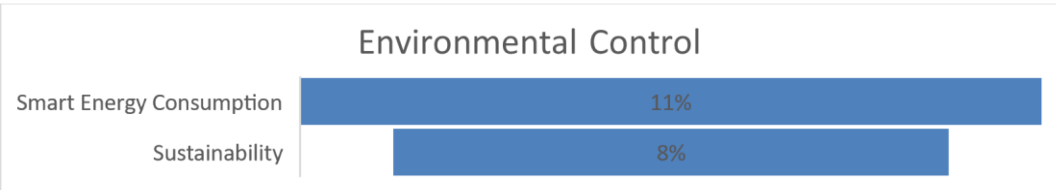


Figure 54 Environmental Control (Spain)

While concern for environment is very important yet there has been no prominent interest here with only 11% projects caring about it. On Environmetal Performance Index Spain is ranked twelth, scoring 78.39. The country ranks first for water and sanitation and second for clean air and environmental health. While these are all positive aspects that might be a reason why the country doesn't have to specifically spend heavily on environmental control yet there can be future concerns as more than 60% of the electricity production in country comes from fossil fuels [72].

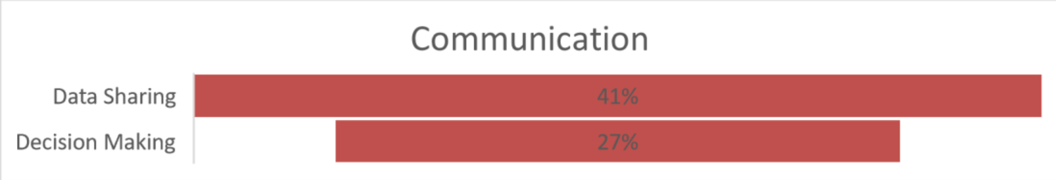


Figure 55 Communication (Spain)

Data sharing account for 41% of the studied projects while decision-making accounts for only 27% of the projects. While Spain lags behind in digitalization within EU, it is recently that the country has realized to improve its position. Blockchain technology which has started to be embraced by several countries is gaining a stronger trend in Spain now. The technology is changing the way government and banks work. Company like Technalia is currently working heavily on working with blockchain technology and experimenting [73].

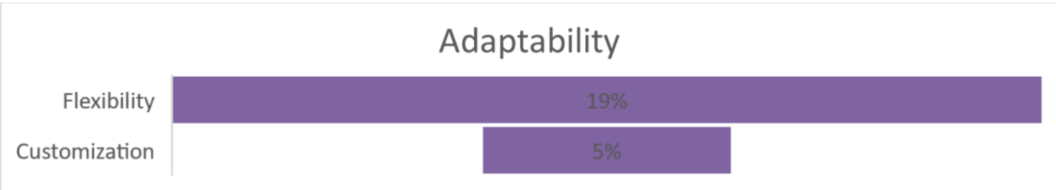


Figure 56 Adaptability (Spain)

19% of the projects are flexible enough to be adopted, a possible reason could be the fact that majority of the project are research oriented and currently in the phase of development towards a unique goal instead of offering any flexibility.

3.4.4 Italy

Italy is among the six leading manufacturing countries, second in Europe only to Germany. It also has the 3rd largest economy in the EU zone [74]. According to the information on export.gov, Italy is second leading manufacturing country in Europe and has great expertise in many key sectors such as machining, automotive, pharmaceuticals, food and fashion. As a rough estimate the manufacturing accounts for 23.5% of the country's GDP. Its approximate manufacturing trade is valued at $63.2 billion [75]. Manufacturing is the backbone of the country and drives the economic growth and development. Italian companies are able to generate major part of wealth and employment for the nation and contribute heavily in finance, economy and social stability [74].

National Initiative: Industria 4.0

In February 2017 The Italian Ministry of Economic Development adopted the National Plan for Industry 4.0 [76]. The new strategy was put in place for horizontal measures taken to encourage enterprises to invest in new technology, R&D projects and elevate the completeness of the Italian manufacturing companies. The goal of the plan is to raise the incentives on taxes for investments in materials and technologies which integrate the physical system with the digital system. This allows complex analysis such as big data and next generation manufacturing systems to be put to use in real. The program over the initially planned period of 2017-2020 covers a wide array of measures to be taken over a short and medium term. These tasks are aimed to collectively develop a foundation for an efficient framework. To this end, the government plans to spend about €18 billion over the said period [76].

Table 7 Strategic and Complementary Measures by the Italian administration [77]

Strategic measures		Complementary measures	
Innovative investments	**Skills**	**Enabling Infrastructures**	**Additional support measures**
• Stimulate private investments in I4.0 technology drivers • Increase private expenditure in research & development & innovation • Expand open innovation relationships between mature companies and high-tech startups	• Spread the I4.0 culture through *"Scuola Digitale"*[1] and *"Alternanza Scuola Lavoro"*[2] programs • Develop I4.0 skills through vocational training, strengthening *"Istituti Tecnici Superiori"*[3] • Finance the I4.0 Technological Clusters and Industrial PhDs • Create Competence Centers and Digital Innovation Hubs	• Ensure adequate network infrastructure – Ultra Broadband Plan • Cooperate in the definition of IoT open standards and interoperability criteria	• Channel finance to support the I4.0 transformation: Private Debt/Equity, VC • Support Public Guarantee scheme on investments • Reinforce internationalization of Italian companies • Strengthen the productivity-salary taxation exchange and decentralized negotiation

To boost and strengthen I4.0 several measurements have been taken by the administration. This included the Ultra Broadband Plan, whose purpose is to ensure a strong network infrastructure (30Mbps connection to companies by 2020, with half of them having 100Mpbs). A collaboration between important stakeholders is formed to define different standards for IoT and a measure to trigger investment from the private sector for the support of I4.0 especially through venture funding and private equity [78].

The figure below represents the key analysis of Industria 4.0 [77]

Funding Models	• Funding model based on public funds earmarked for implementation of specific measures in order to create favourable conditions boosting private investment in technology, innovation, R&D
Target Audience	• Companies and entrepreneurs, regardless of the size, sector or location
Focus Area	• Take full advantage of opportunities related to the fourth industrial revolution, promoting investments in innovation, intangible assets and R&D, spreading the culture related to “Industria 4.0” and developing skills
Result Obtained	• > €10 bn. private investment increase in 2017/2018, +11 bn. R&D&I private expenditure in 2017-20, 200.000 academic students and 3.000 managers qualified in I4.0, doubling the students in vocational schools on I4.0 topics
Budget	• More than €18 billion for the period 2017-2020
Unique Factors	• Parallel focus on technology and development of skills necessary for the successful digital and technological transformation. A wide variety of fiscal incentives available for companies of any size, sector and location.
Expected Impact	• New development of I4.0 skills, uptake and diffusion of new technologies, expansion of R&D activities; increasing the competitiveness of Italian companies and industry.

Core Activities

The main activities involve invention in innovation, triggering private investment to support I4.0 technology, R&D expenditures and skill development programs.

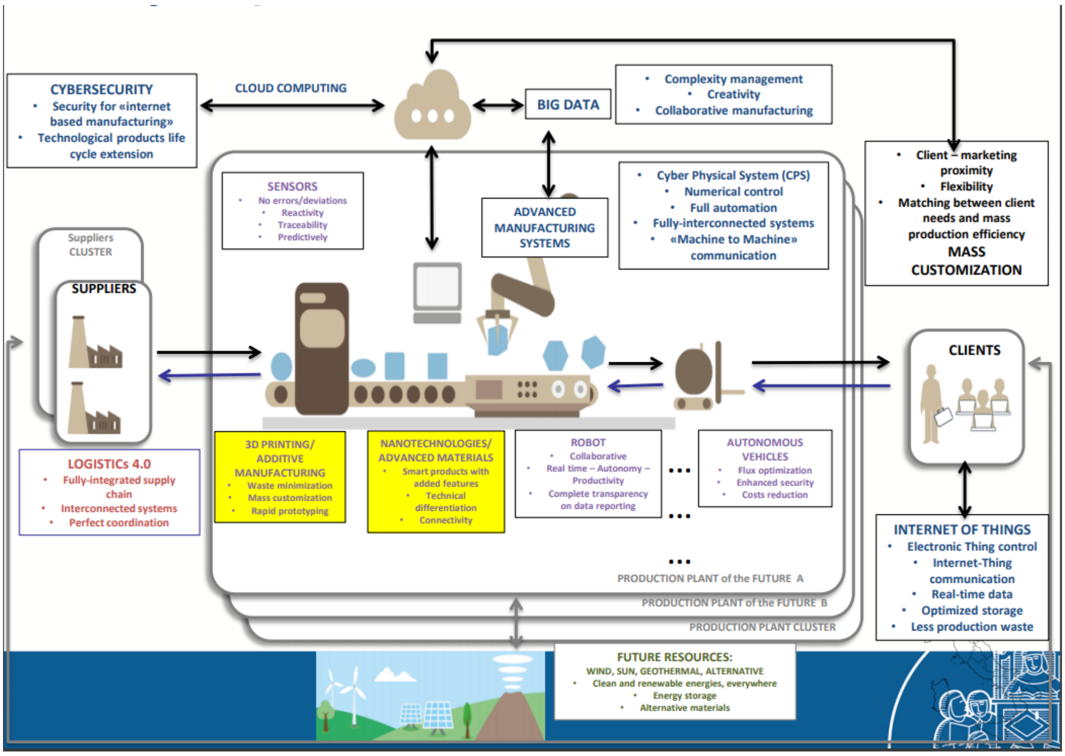


Figure 57 Pictorial depiction of Industry 4.0 plan in Italy [77]

Important Public Private Partnership: MADE

Recently there was an announcement of a new public private partnership between Politecnico Di Milano and Comau (an industrial automation and robotics company) to open a competence center called MADE. A huge financial commitment is meant for this program worth €22 million spread over three years. Half of the investment will come from the Ministry of Economic Development while remaining from the private stakeholders. Furthermore, €14million will be used for equipment's and personnel while remaining €8 million for applied research and technology transfer projects [79].

A 2000 m^2 area is dedicated to this center at Politecnico Di Milano and will become active by September of 2019.The strategic and design of MADE are in line with Italian and European region demonstrating the industrial policies, research and innovation-based activities directed towards Industry 4.0. In medium term, the objective is to reach 10,000 people over the next three years in terms of information and propagating the activities on potential digitalized technologies. Other objectives involve 86,000 man-hours of training and developing more than 390 project and having up to two hundred digital assessments with involvement of more than 15,000 Italian companies. More than 80% of such companies are expected to be SMEs [79].

The private partner Comau will be providing its high-tech solutions to the competence center such as MATE exoskeleton, Agile 1500 (an autonomous vehicle), industrial robots, collaborative robots and e.DO which is an educational robot. Expert guidance training and other operational support services will be provided by them [80].

Future Perspective

According to the survey conducted by export.gov, 64% of the Italian metalworking and machine companies are applying one of the advanced technologies in manufacturing process [75]. This include, cloud computing, robotics, IoTs, additive manufacturing, advanced machining and cybersecurity to name a few. 82% of the entrepreneurs in Italy believe that the key to the future of manufacturing sector in Italy lies in automation as per estimate by Accenture [75].

While it is hard to say how the future will unfold, but there is a long way for Italian manufacturing industry to overcome many barriers in order to maintain its historically high position in manufacturing. The government would need to provide incentives to companies so that they can easily invest in new capital goods, advance technologies, digital transformation tools for their production and other IT based software. Private support is crucial for growth and competence centers need to be developed all over Italy for fast approach and applied research. Bank loans must also be made easy as there are difficulties faced by businesses and other professionals due to insufficient guarantees.

Analysis of Italian Manufacturing Market

During the research phase approximately 43 projects were reviewed. These projects have been carried out by the Italian companies or research institutes.

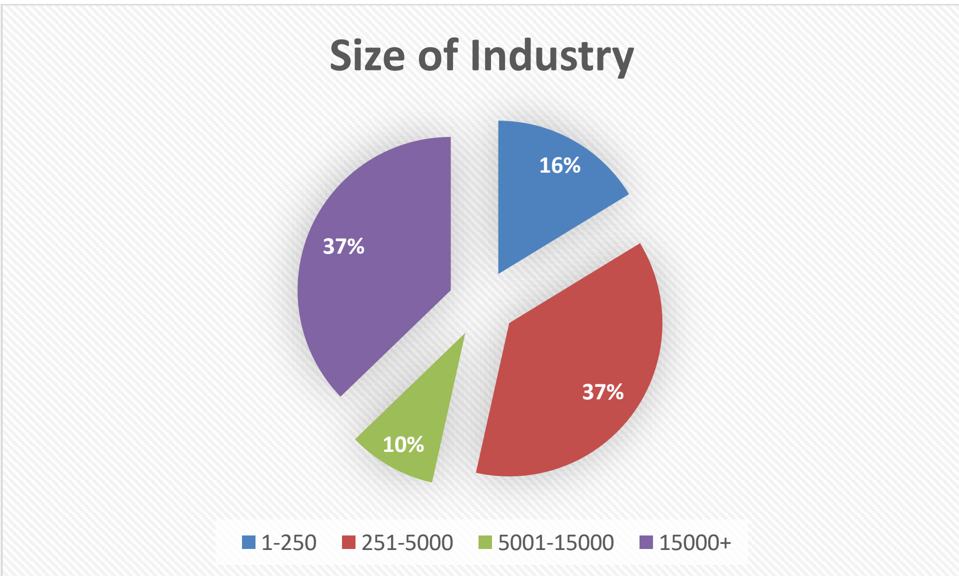


Figure 58 Size of Industry

Small and medium enterprises are more interested in carrying out projects accounting for 74% of the projects in total. The reasoning remains the same that big companies do not feel the threat but also have limited interest in taking risk over new technology.

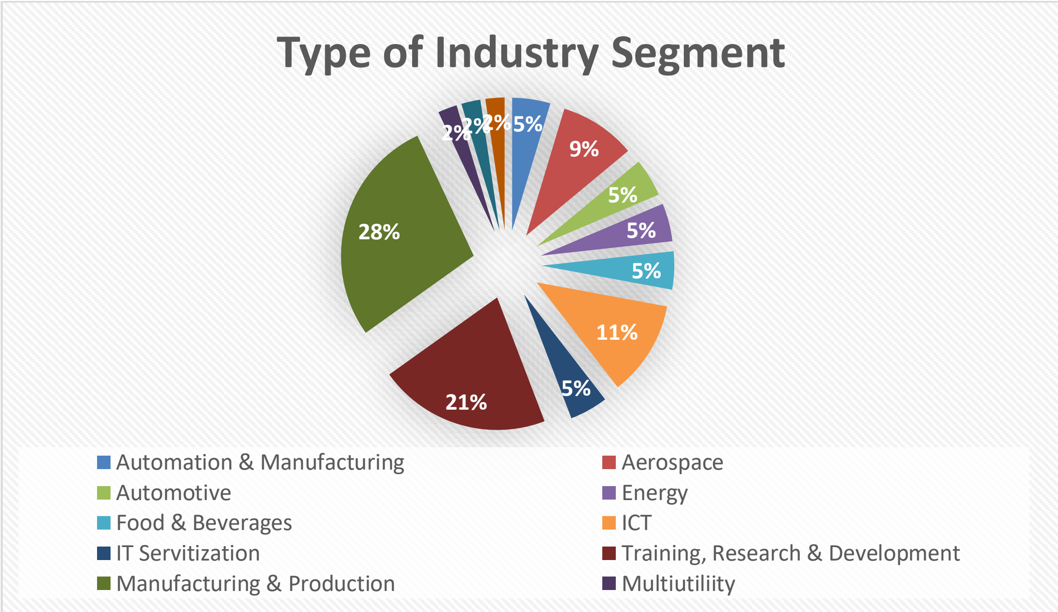


Figure 59 Type of Industry Segment

It was interesting to find that projects from different industry sectors are working on projects related to Industry 4.0. Majority of projects roughly 28% followed by 21% were related to manufacturing & production and aerospace respectively.

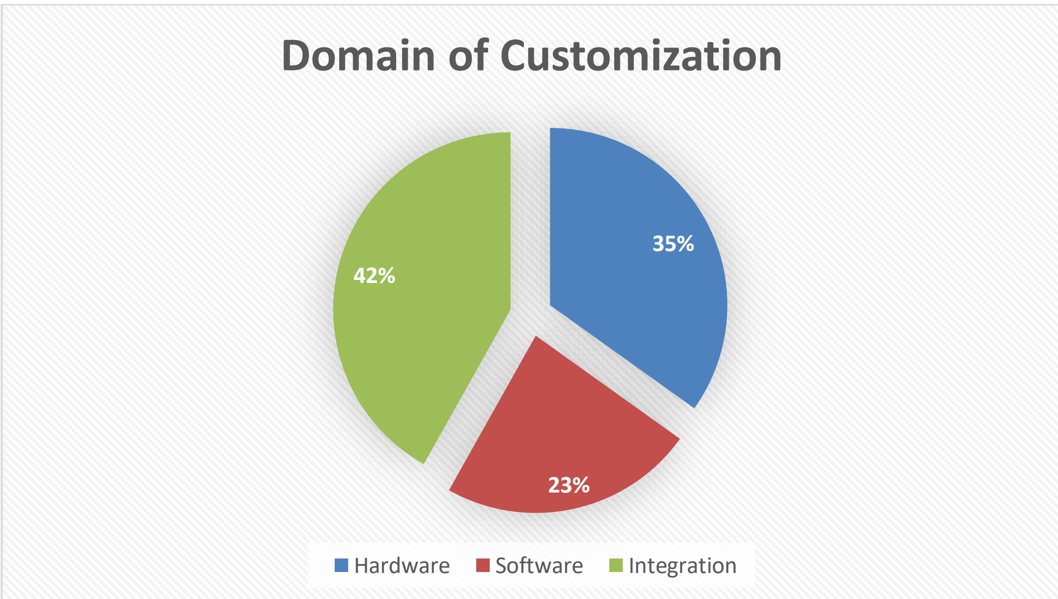


Figure 60 Domain of customization

Majority of project studied were related to integration customization accounting for 42% followed by hardware (35%).

Technological Tools

Technological tools were used in order to measure the progress that each project was aiming at. Figure 61 represents the graph for the technological analysis of projects carried out in Italy. Looking at the graph it is evident that the top two tools used by the companies in Italy are major I4.0 tools (58%) and IOT (49%). It is also interesting to note that 9% of the projects are related to CPPS which is much higher as compared to other EU countries although still a lower percentage in general. Digital Virtualization (DIVE) is one such prominent project initiated by Engineering Ingegneria Informatica SpA in collaboration with Comau. It is Industry 4.0 compliant and will be managed very easily to enable a virtual manufacturing system that would exchange data and command with the physical plant.

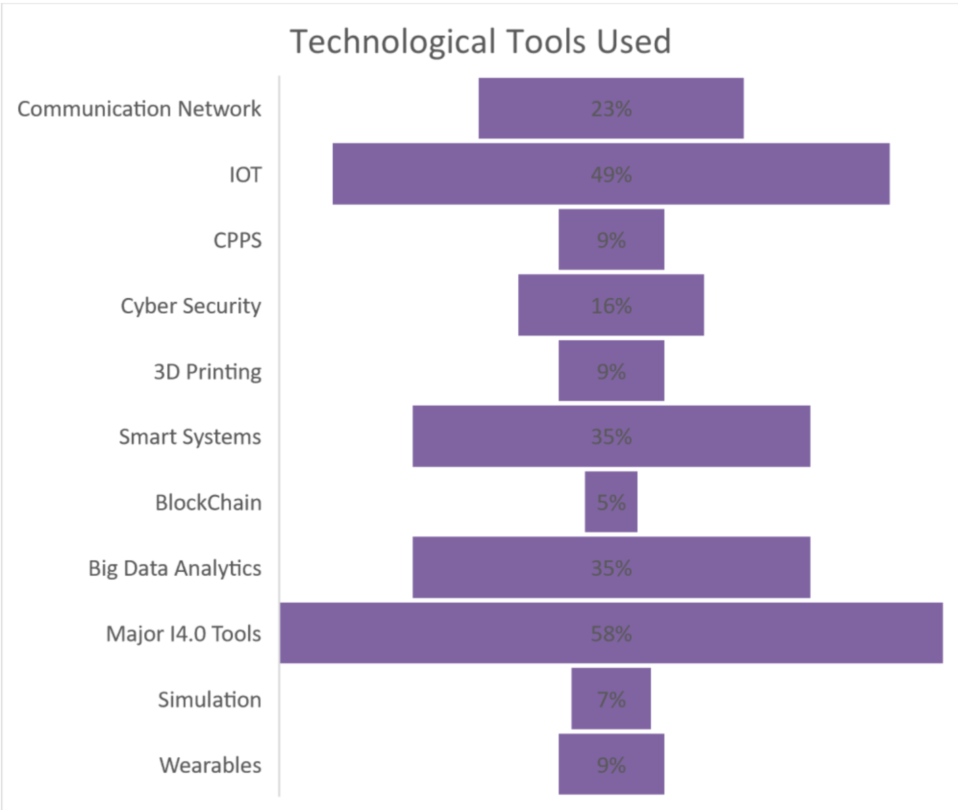


Figure 61 Technological Tools (Italy)

If we further look in depth of our technological tools analysis; the smart systems, major I4.0 tools, communication network was broken down into further elements.

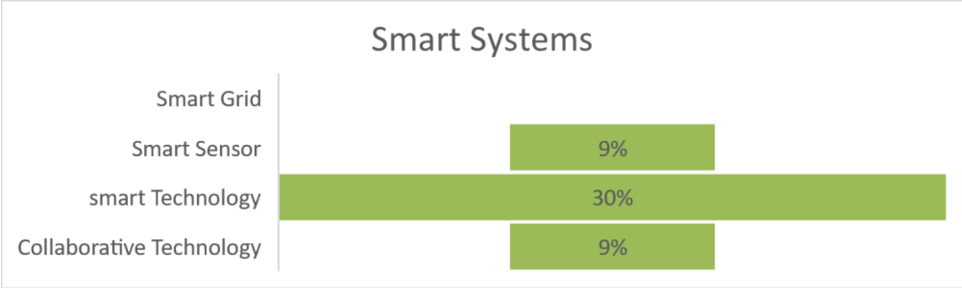


Figure 62 Smart Systems (Italy)

In Italy the focus remains on smart techology, which covers a combination of technology related to RFID, certain sensing modules combined to other smart modules.

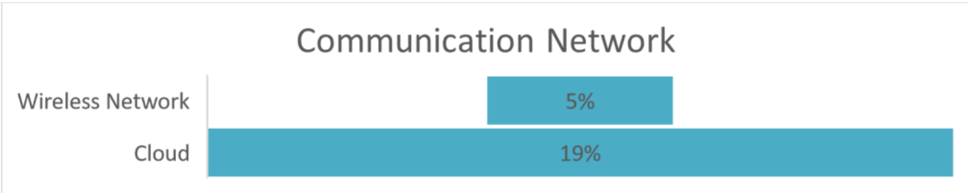


Figure 63 Communication Network (Italy)

Cloud technology is on rise in Italy and the work on ICT related technology. From the studied projects we see 19% were involving cloud technology in some form.

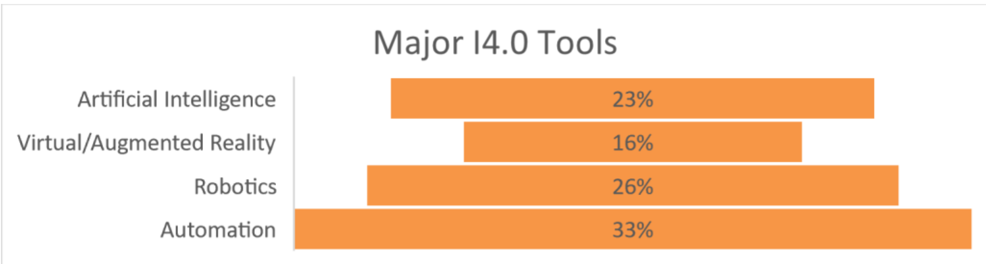


Figure 64 Major I4.0 Tools (Italy)

Major I4.0 tools were used by 58% of the studied projects. There is no abnormal trend noticed with automation as leading tool in 33% of the projects to virtual reality (16%) as least spend tool.

Non-Technical Tools

Italian projects were not very focused on non-technical tools with only 14% projects revolving around educational tools. According to a 2013 survey by UNESCO Institute for Statistics, it was noted that majority of manufacturing industries were not interacting with public research institute. Among the high-income countries surveyed, the university-industry ties were lowest with only 5.3% of collaboration in Italy [81]. One explanation for such trend in high-income countries could be the possibility that university does not consider technology transfer as a reliable supplement to revenue due to its unpredictable nature.

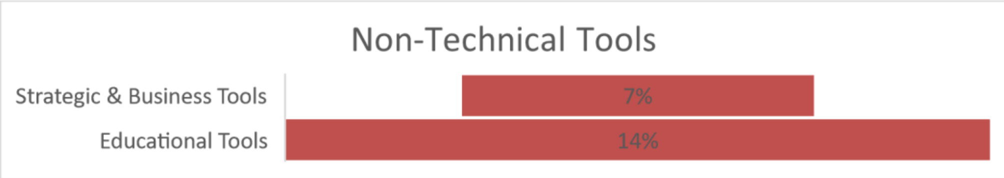


Figure 65 Non-Technical Tools (Italy)

Targets and Expected Outcomes

Following are the outcomes of nine different targets for projects studied. It is evident that the top two targets set out by these projects are operational target, and communication. 93% of the projects had operational targets while 63% communication.

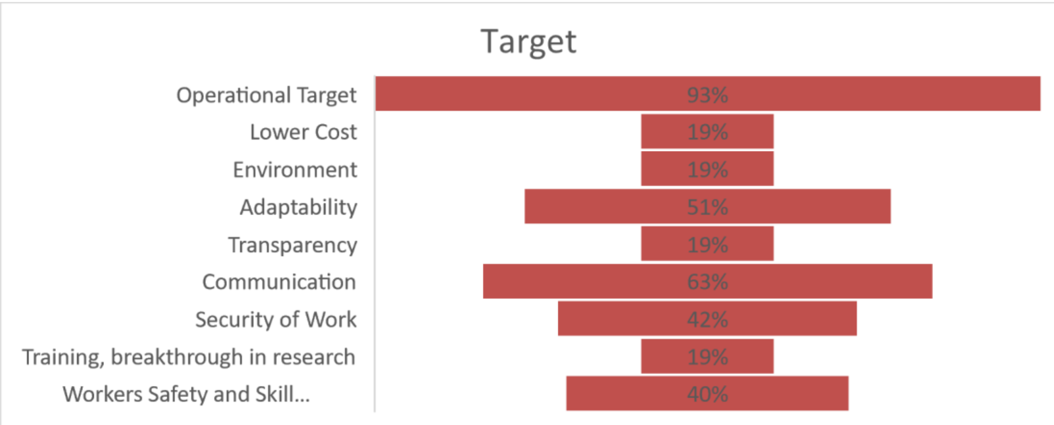


Figure 66 Target (Italy)

As mentioned earlier, some targets are subdivided into elements, this include operational target, environment, adaptability, and communication. Following table list down the lower elements.

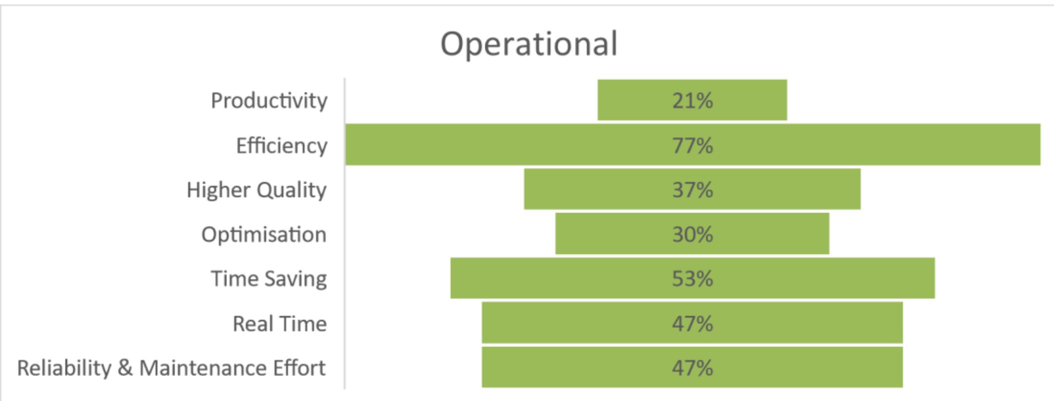


Figure 67 Operational (Italy)

In the figure above, we see efficiency (77%), time saving (53%), real time (47%) reliability & maintenance effort (47%) as four most important operational targets set by majority projects. Real time control is more important and linked to data collection particularly focused on big data.

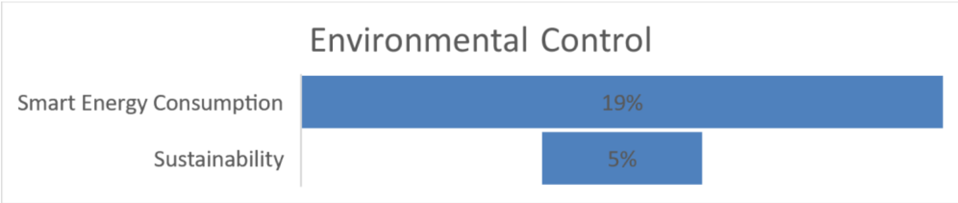


Figure 68 Environmental Control (Italy)

While concerns for environment is very important yet there has been no prominent interest here with only 19% projects caring for smart energy consumption. The current economic factors can majorly influence clean technology progress in Italy and hence it is important to foucs on projects that are environmentally safe and smart.

International Energy Agency's report made three recommendations on how Italy can improve itself environmentally [82].

4 A national energy sector should be developed which is consistent with modern market for energy
5 The Italian administration needs to identify and adress deficiencies existing in its energy infrastructure
6 The country needs to push towards the collective goal of climate control under EU 2020 plan.

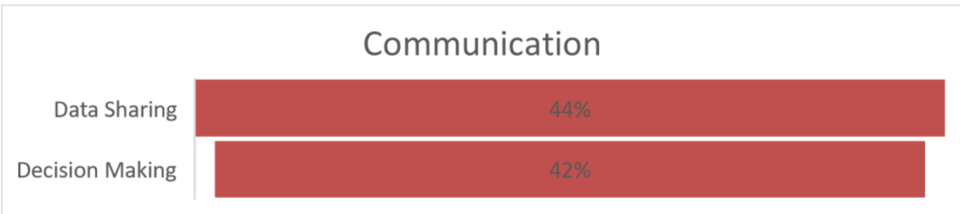


Figure 69 Communication (Italy)

Data sharing and decision-making accounts for 44% and 42% respectively for all the projects studied. This shows a positive trend, something which was lacked when studying the French industry.

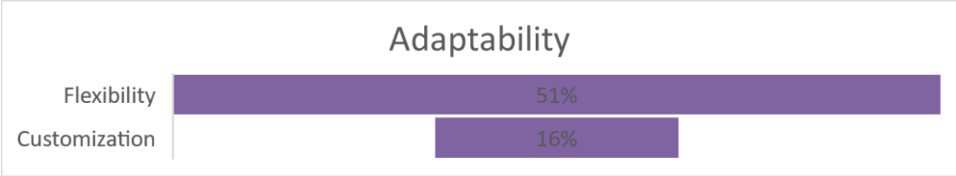


Figure 70 Adaptability (Italy)

51% of the projects are flexible enough to be adopted which indeed is a good number. Project flexibility allows them to be managed more successfully and cover a range of problems. It helps to utilize less resources when changes arise. It is also important to identify and develop project boundaries which are flexible and to what level as it helps in future to clearly identify the scope [83].

3.4.5 UK

There has been a growing curve for the disruption of technology in UK. Multitude of factors are leading to technological innovations and a changing behaviour in customers. At the same time global landscape is also changing as we discussed earlier. Fast paced innovation is a need of time to compete with world powers. Industry 4.0 comes at the right time and can offer a great opportunity for UK to position itself as a global excellence centre for advanced manufacturing.

UK is also faced by another major situation of attention, where it is very close to leaving EU commonly known as Brexit. Brexit can have a greater impact on the manufacturing sector as it will change the aid rules, trade regulations and the change in workforce which are all the factors critical for the growth of this industry.

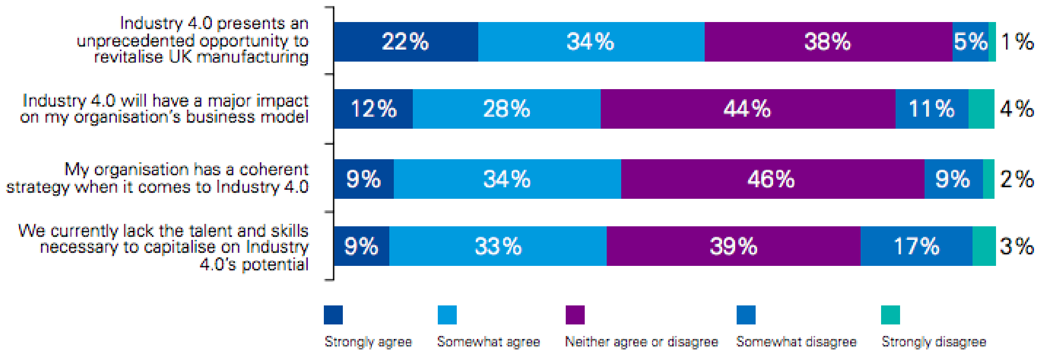


Figure 71 Recorded responses from Industries across UK by KPGM [84]

UK Government is looking for an interconnected strategy for the industrial sector in order to cope with the challenges faced by the UK economy and address them in a better way. These measures are meant to increase productivity and increase innovation [85].

According to Stephen Cooper, Head of Industrial Manufacturing, KPMG UK, “There would be far more connected infrastructure due to Industry 4.0, which will blur the lines between traditional sector and hence this require a greater collaboration to make it possible” [84].

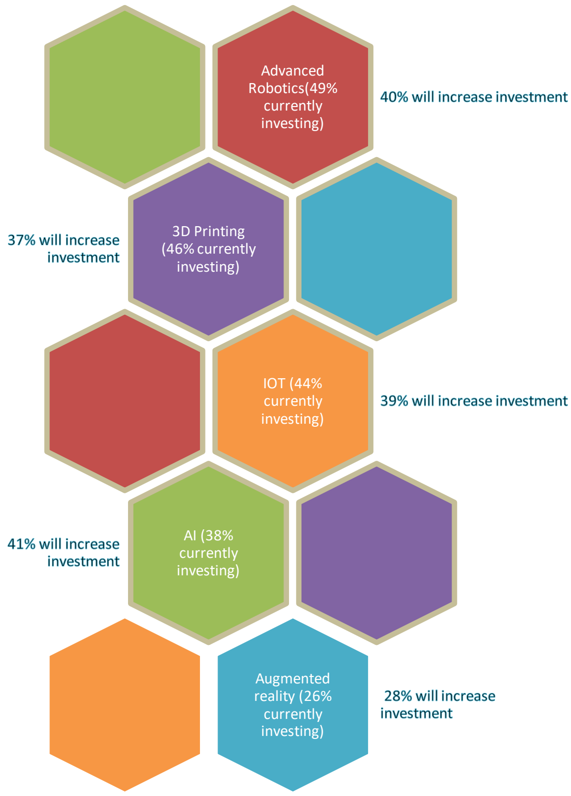


Figure 72 What investment are UK manufacturers currently making into new technologies (current investment – over next three years)

The survey conducted by KPMG has seen that there is more enthusiasm rather than preparedness for the new industrial revolution. According to the survey 56% respondents think that I4.0 will present a huge opportunity to reshape the UK manufacturing but at the same time majority respondents are unsure how their business will be affected due to this change and whether if they have a strategy or right skillset to capitalize on this.

Midsize companies are more positive and 49% consider that they have a strategy to take advantage of Industry 4.0 compared to large companies where only 37% have an optimistic view. At the same time midsize companies (54%) believe that I4.0 will have a major impact on their business compared to large companies (35%).

According to Charlie Simpson, Partner with Global Strategy Group at KPMG UK, “Many UK businesses are struggling with their day to day business, hence despite their enthusiasm, it is very difficult to see a major investment or a business case of implementation”

There are structural issues in UK manufacturing that don't help. Simpson argues, for instance, that the UK, unlike Germany, lacks the volume of major players and smaller investors that can help drive the coordination and standardisation of technology required for Industry 4.0 [84].

Possible Effects of Brexit

In the short-term, the game changer for UK manufacturing will prove to be Brexit. Nearly half of respondents, for example, think R&D activities will increase in the next three years, as well as an increased investment in Industry 4.0 technologies, including artificial intelligence, advanced robotics, the Internet of Things and augmented reality. 45% of the manufacturers believe that a 'hard Brexit' will have a negative impact on their organization.

"Brexit will force a paradigm shift. It could be putting a new CEO in place, leading to a new strategy, or it might be taking a fresh pair of eyes to the whole process, breaking it down, mapping it out and implementing practical process improvement." Nick Harrison, Partner, 45% KPMG in the UK

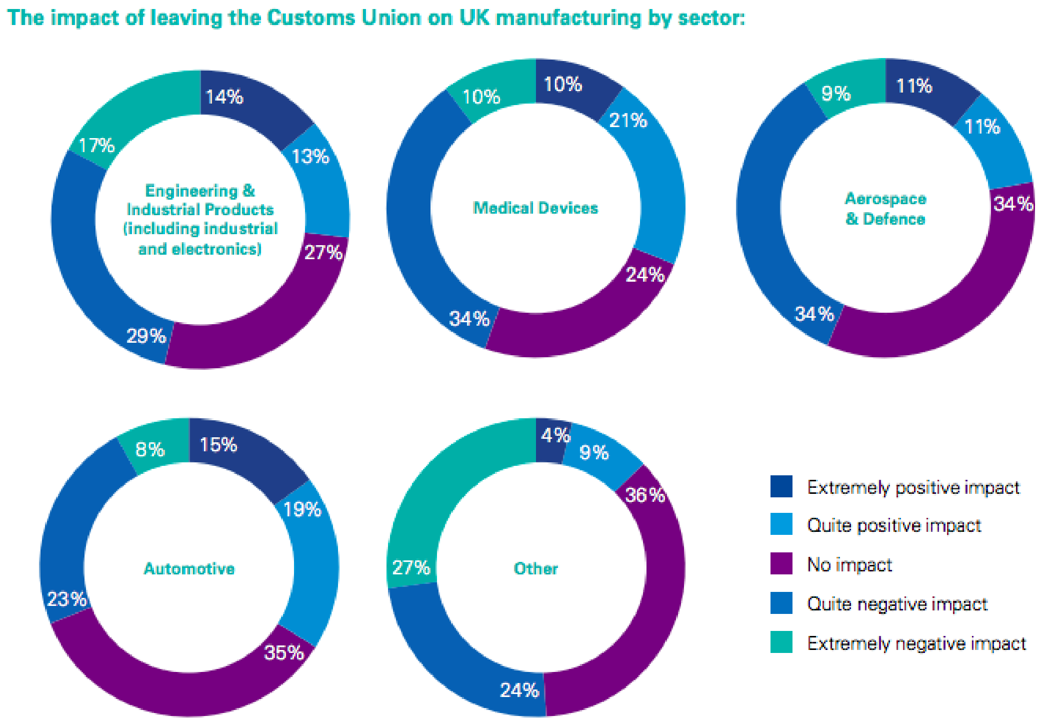


Figure 73 The impact of leaving the Customs Union on UK manufacturing by sector [84]

National Initiative: Industrial Strategy

The Industrial Strategy sets out a vision for the future economy and this strategy is to boost the productivity, earning power and quality of life of the British people. By 2030, British wants to transform productivity and earning power across the UK to become the world's most innovative economy and the best place to start and grow a business, with upgraded infrastructure and prosperous communities across the nation [85].

UK has committed to the biggest ever increase in public and private investment in research and development. Public infrastructure funding which will be doubled in a decade by 2022/23 and through local industrial strategies working with local leaders, the goal is to build the most dynamic economies. We are reforming our technical education system to make it as prestigious as our higher education system, and we are supporting businesses across the country to boost their exports and productivity.

Analysis of UK Manufacturing Market

During the research phase approximately 16 projects were reviewed. The limitation of projects was due to very little data available about projects related to Industry 4.0.

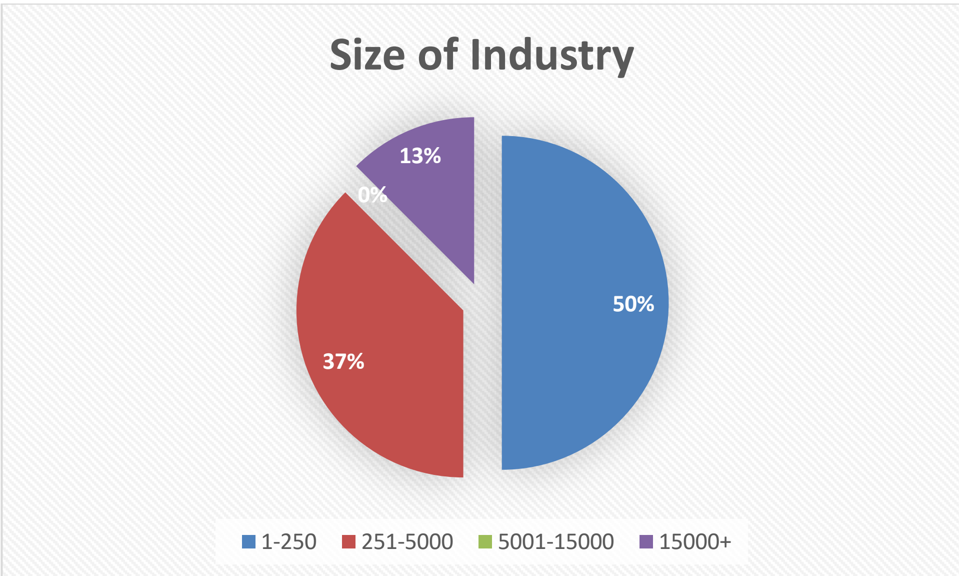


Figure 74 Size of Industry

Small and medium enterprises are more interested in carrying out projects accounting for 87% of the projects in total.

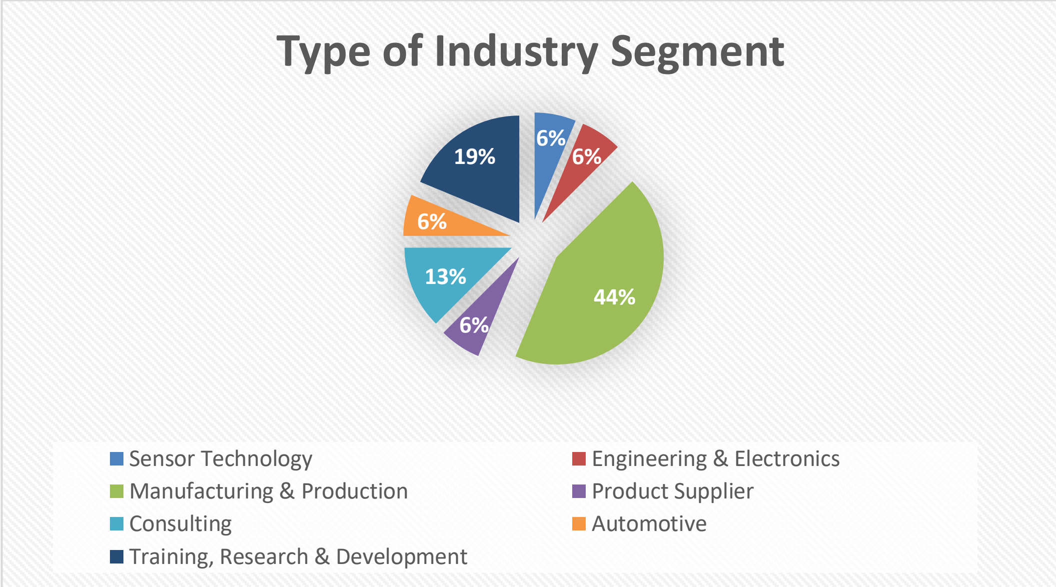


Figure 75 Type of Industry Segment

It was interesting to find that projects from different industry sectors are working on projects related to Industry 4.0. Majority of projects (roughly 44%) are related to manufacturing & production.

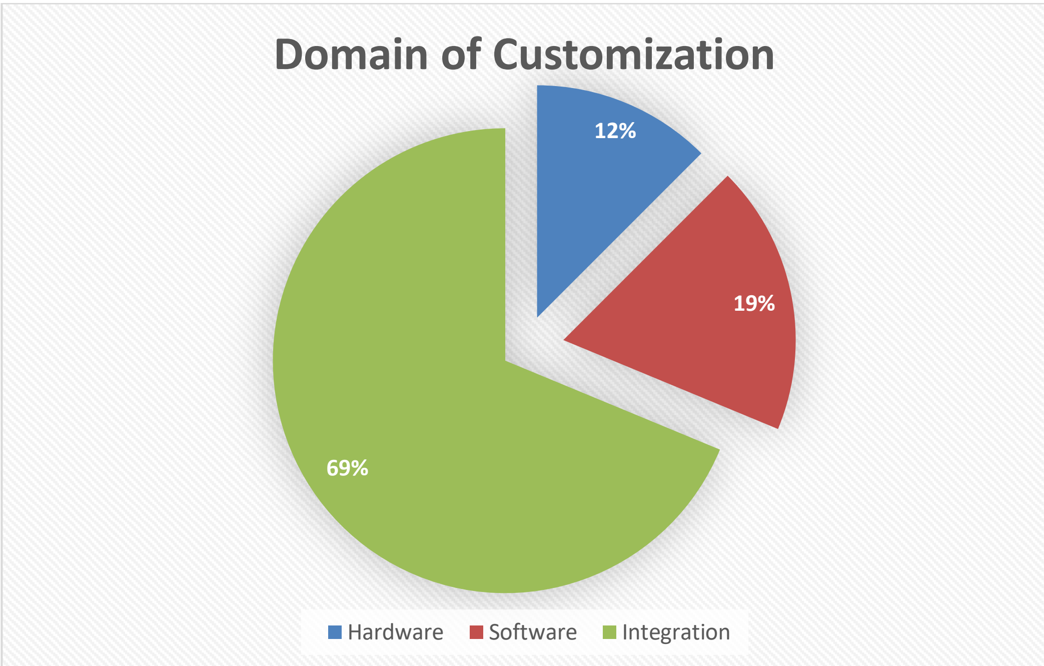


Figure 76 Domain of customization

Majority of project studied were related to integration customization accounting for 69%.

Technological Tools

Technological tools were used to measure the progress that each project was aiming at. Figure 77 represents the graph for the technological analysis of projects carried out in UK. Looking at the graph it is evident that the top two tools used by the companies in UK are major I4.0 tools (63%) and smart systems (81%).

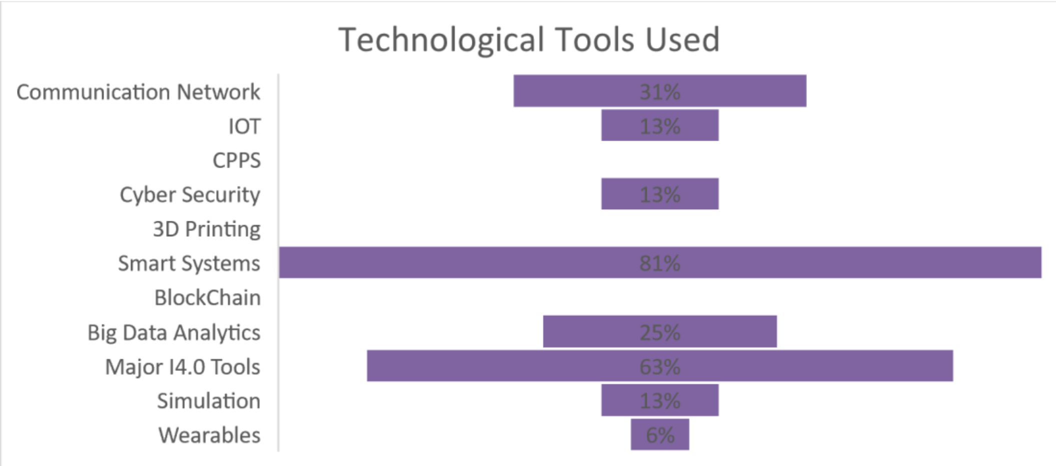


Figure 77 Technological Tools (UK)

As earlier discussed, there was no proper strategy by British administration regarding industry 4.0. The recent Industry Strategy plan set up by the government seems promising and it is expected that business sector of UK will initiate further projects in this regard towards new technology and develop projects using different tools.

If we further look in depth of our technological tools analysis; the smart systems, major I4.0 tools, communication network was broken down into further elements.

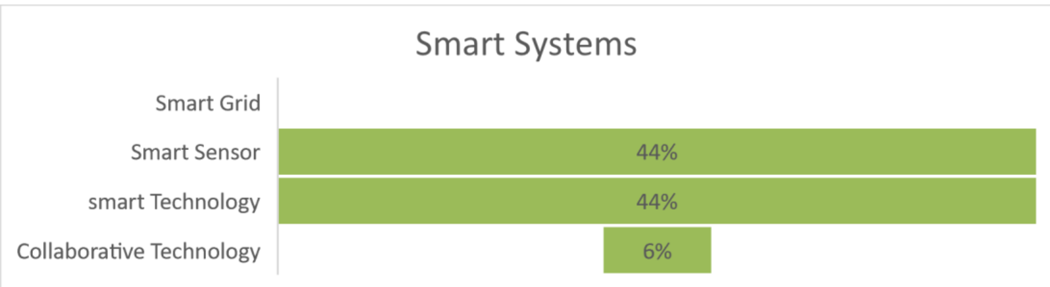


Figure 78 Smart Systems (UK)

In UK the focus remains on smart sensors and smart technology with 44% projects involved. The smart sensor market was estimated to be worth $360 million in 2015 and by 2020 it is expected to grow and reach $1028 million [86].

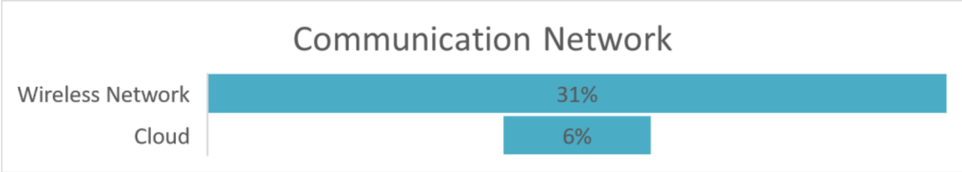


Figure 79 Communication Network (UK)

Cloud technology seems to be a very low focus while 31% of projects are using Wireless Network as a form of communication. According to a global study the main reason behind slow adoption of cloud by British businesses are the issues related to data protection and strict regulations. This less concentration is associated with sectors who must comply with many regulations such as health, finance and petrochemical [87].

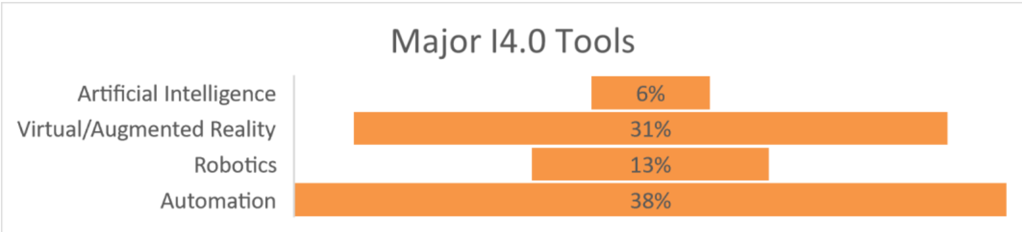


Figure 80 Major I4.0 Tools (UK)

Major I4.0 tools were used by 63% of the studied projects. Automation and virtual reality are two focused tools with 38% and 31% projects having some form of involvement respectively.

Non-Technical Tools

UK is more focused on strategic and business tools, yet the effort seems very less in this regard due to only 13% of projects showing any interest towards any non-technical tools.

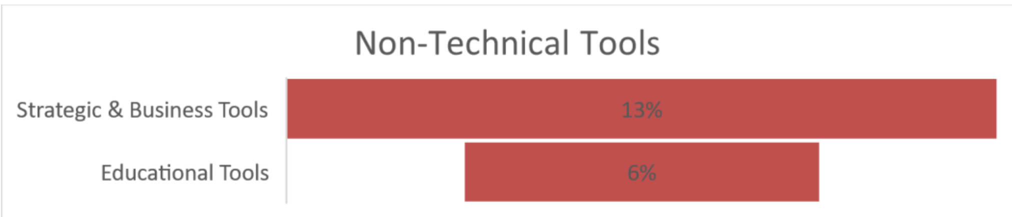


Figure 81 Non-Technical Tools (UK)

Targets and Expected Outcomes

Following are the outcomes of nine different targets for projects studied. It is evident that the top two targets set out by these projects are operational target, and workers safety & skills. 100% of the projects had operational targets while 50% on workers safety and skills.

Figure 82 Targets (UK)

As mentioned earlier, some targets are subdivided into elements, this include operational target, environment, adaptability, and communication. Following table list down the lower elements.

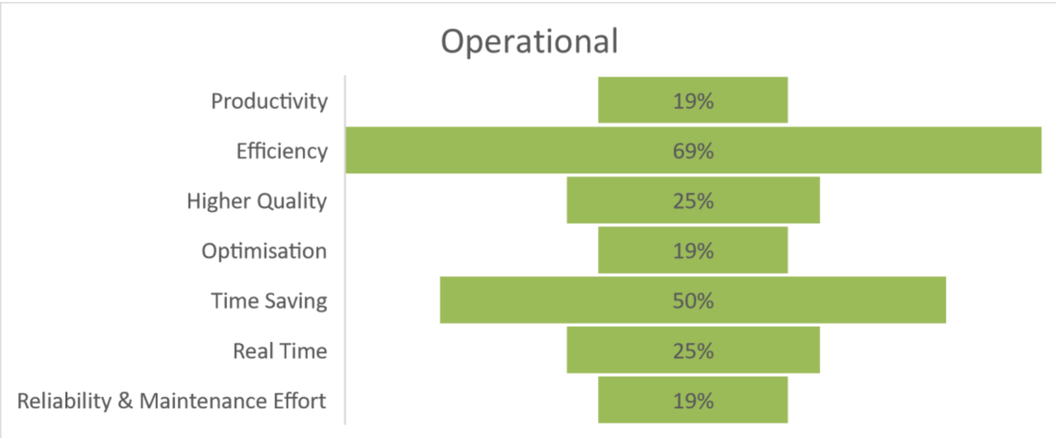


Figure 83 Operational (UK)

In the figure above, we see efficiency (69%), time saving (50%) are two most important operational targets set by majority projects.

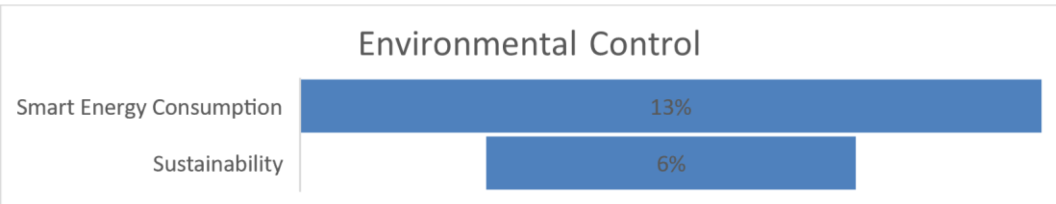


Figure 84 Environmental Control (UK)

Environmental control was very low and only 13% of the projects cared about smart energy consumption. On 14 January 2019, UK administration launched an ambitious new strategy towards clean air. According to one report air pollution is a leading threat to public health in UK, just behind cancer, heart disease and obesity. The strategy called Clean Air Strategy aims to reduce the cost of air pollution by £1.7 billion every year and raising it to £5.3 billion by year 2030 onwards. At the same time the administration has launced a joint research program with UK Research and Investment, leading to an investment of £19.6 million in order to promote technology that is cleaner and greener. This fund has been directed through the Industry Strategy already discussed [89].

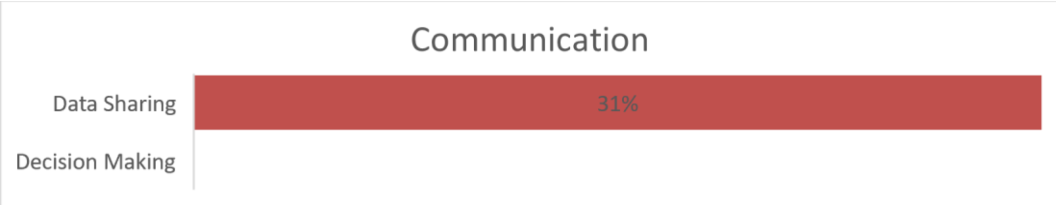


Figure 85 Communication (UK)

Data sharing accounted for 31% of the projects while there was no knowledge available on any project where decision making was a possible target.

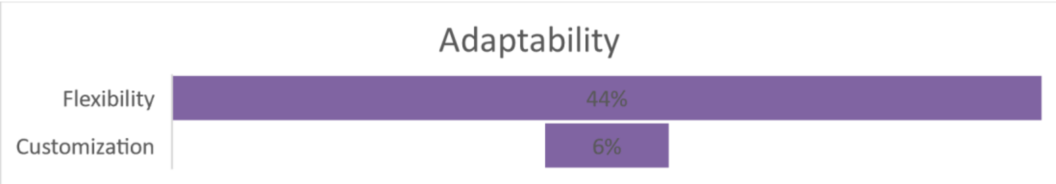


Figure 86 Adaptability (UK)

44% of the studied projects are flexible and can adapt to various conditions or settings. But at the same time, it cannot be implied on a larger scale as the possible study cases were limited to only 16 projects.

3.5 Overview of the Analysis

Table 8 summarizes all the studied projects based on the tools and targets for each element. A general comment is drawn to conclude every element. The table also helps in understanding how every country compare to each other and EU in general.

Table 8 Summarized Table comparing EU countries

	Germany	France	Spain	Italy	UK	EU	General Comment
Development Program	Industrie 4.0	Industria du Futur, French Fab	Industria Conectada 4.0	Industria 4.0	Industry Strategy	Horizon 2020	
Size of Industry	1-250	50-250	1-250	251-5000	1-250	1 - 250	Majority of the new technology or research is implemented by startups or small industries

Type of Industry Sector	Manufacturing & Production	Automation & Manufacturing	Training, Research & Development	Manufacturing & Production	Manufacturing & Production	Manufacturing & Production	Manufacturing and production is the main field where the new projects are carried out
Domain of Customization	Integration	Hardware	Software	Integration	Integration	Integration	Integration is preferred domain of customization except for Germany and France where hardware is majorly preferred.
Technological Tools	Smart Systems	Major I4.0 Tools	Major I4.0 Tools	Major I4.0 Tools	Smart Systems	Major I4.0 Tools	While in EU focus lies on I4.0 tools
CPPS	16%	-	3%	9%	-	7.3%	CPPS is not well sought out tool yet but Germany had a bigger share over research in this field
Non-Technological Tools	Educational Tools	Strategic & Business Tools	Educational Tools	Educational Tools	Strategic & Business Tools	Educational Tools	Educational tool is important to develop highly skilled workforce for the future jobs.
Smart Systems	Smart Technology	Collaborative Technology	Smart Sensors	Smart Technology	Smart Sensor/ Smart Technology	Smart Technolgy	Smart technology is utilized almost everywhere for innovative methods
Communication Network	Wireless/Cloud	Wireless/Cloud	Cloud	Cloud	Wireless	Cloud	Digitalization can be only seen fully accomplished when cloud computing is preferred way of communication
Major I4.0 Projects	Automation	Robotics	AI	Automation	Automation	Automation	While Automation is focused in EU, research in AI was more seen in projects by Spain
Targets	Operational Targets	Operational Targets	Operational Targets	Operational Targets	Operational Targets	Operational Targets	Every country has some operational targets
Operational Targets	Efficiency	Productivity	Efficiency	Efficiency	Efficiency	Efficiency	While efficiency is sort out more in EU countries while French projects are more directed towards productibity
Environmental Control	Smart Energy Consumption	Smart Energy Consumption	Smart Energy Consumption	Smart Energy Consumption	Smart Energy Consumption	Smart Energy Consumption	Environmental control is still very low in every EU country without any major efforts shown particularly in projects
Communication	Data Sharing/Decision Making	Data Sharing/Decision Making	Data Sharing	Data Sharing	Data Sharing	Data Sharing	For a future connected industry data sharing is crucial
Adaptability	Flexibility	Flexibility	Flexibility	Flexibility	Flexibility	Flexibility	Majority of projects are flexible enough to be utilized for multiple purposes

This table is an overview of all the following elements that were studied for every country individually:

1. Domain of Customization
2. Size and type of Industry
3. Technical and non-technical tools
4. Targets

The following are the major differences being observed between the EU countries from the projects studied:

1. **Majority of attention for new technologies across EU comes from startups:** Entrepreneurship is gaining ground across EU. Many innovators or small firms are taking a big step towards disruptive technology. Small firms want to get bigger pie of the market through new technology while the large companies are less focused on change as they fear less due to a dominant position in well-established market space.

2. **Manufacturing and production a major drive across EU:** Manufacturing is one of the most focused area by every EU country studied. This is because of the powerful impact manufacturing industry have on the economy of these countries and hence the governments individually are also devising strategies to develop the manufacturing industries.

3. **Integration as a preferred domain:** In I4.0 the preferred domain of customization should be associated both on software and hardware level. This is observed in majority of the projects studied but interestingly France is mainly focused on hardware integration where the country is mostly applying robotics and automation machines to manufacturing sector.

4. **Assessing technical and non-technical tools:** Germany being ahead in technological terms is applying smart solutions to its industries and rest of the EU countries are focused on applying technology such as Automation, Robotics, VR and AI (mostly researched in Spain). CPPS is more focused in Germany, followed by Italy but is not well researched in other countries around EU. Cloud computing despite its unacceptable position in data sensitive industries is still having a stronger acceptance across all the countries of EU. Education tools are more focused across EU.

5. **Targets:** Efficiency is one of the major targets set my all of the countries. An efficient process can automatically benefit productivity, cost and time. Communication is still not well focused target but since data collection and sharing is important part of I4.0 concepts therefore all the countries are focused on it in some ways. Smart energy consumption is also a focused area as it is very important to care about environmental concerns. Most of

the projects across all the countries are flexible enough to be implemented on multiple different platforms, new projects and different situations.

Chapter 4

NON-EU & Industry 4.0

4. Introduction

Major stakeholders outside EU include America, China, Japan. In these countries the term Industry 4.0 is not very common but yet gaining its ground. A major reason is the fact that many different names are used which explain roughly the same concept and idea revolving around Industry 4.0. This could be smart manufacturing, Society 5.0, Made in China 2025 etc. Many companies outside EU has also realized the strength of fourth industrial revolution. Telecommunication and IT companies are investing into revolutionary research and development. Government administrations are also rolling out strategies to motivate companies in investing and creating educational programs to develop the technical skills for jobs of tomorrow.

This chapter will go through America, China and Japan to discuss about their progress in Industry 4.0 and then a final analysis will be drawn on how projects in each of these countries are making the country progress towards I4.0.

4.1 Analysis of Non-EU Countries

To continue further in this chapter, we will discuss the initiatives taken by the most prominent Non-European countries and their status in both educational research and practical implementation.

4.1.1 China

China failed to gain an opportunity during the first and second Industrial revolution. The western world of industrial manufacturing dominated during that time while China lagged behind. It was the end of the 20th century when China seized a very important opportunity and took advantage of the third revolution [89]. This was when globalization was at full swing, and every major developing country was trying to push its limits to manufacture export quality goods. Third revolution added a huge boost to China's economy. When China reformed itself and opened up its manufacturing structure then the four decades turned China into the world's factory and Made in China was a common phrase all over the world due to the lower cost advantage that dominated China over the world.

There is always a limit which cannot be overcome unless changes are made. Such was the case with China. Problems emerged such as overcapacity; a very traditional approach to manufacturing and this is where China is slowly realizing an urgent need to transform and upgrade to competitive manufacturing position with new technological tools.

Recently Chinese government has taken keen interest to initiate a supply side reform. This is to restructure the whole industrial setup by investing in emerging and high technologies while at the same time upgrading the sectors which were fully based on traditional methods. Their top priority includes increasing the public goods supply, reduction in costs, destocking, de-capacity and de-leverage [90].

The fourth intelligent industrial revolution has gained a very serious importance in the world and particularly in EU, as discussed earlier. Major manufacturing powers of third revolution are going under a reshaping process and investing heavily in research and smart technologies. This has also garnered attention of China who is the largest manufacturer and supplier of robots. AI and CPPS are the main driving aspects of the future of manufacturing, hence research and investment in smart industries is critical for countries who want to seek dominance. China lies at the very start of this powerful revolution which offers a huge and highly beneficial new and emerging market sector. Given the powerful and advantageous position, China has a firm grip to take faster advantage if it takes immediate steps of transformation from "Made in China" to "Intelligent Manufacturing in China" [91].

National Initiative: Made in China 2025

For China the challenge is quite different. It is not a high rising trajectory of Made in China from being big to Mega. They want to transform from Made in China to Design and Innovate in China [92].

With the growing reindustrialization across the globe and the high-tech strategies implemented by countries surrounding the Industry 4.0 strategy has led the Chinese State Council to announce a new plan, "Made in China 2025". The purpose of this plan is to lay out a strategic road map for the development of economy over the next 10 years from 2016-2025. To chalk out this plan a blueprint was developed by the Ministry of Science & Technology and China's National Development and Reform Commission. Inputs were also taken from additional resources such as Ministry of Industry & Information Technology [93].

This 10-year plan to develop Chinese Industrial sector is an intention to transform the manufacturing sector of China completely. The transformation regards to change from highly labor-intensive production to completely knowledge-based manufacturing. Made-in-China 2025 plan is China's industrial development master plan for the next ten years. The plan signals China's intention to launch an industrial transformation from labor intensive production to knowledge intensive manufacturing, and to implement it at a very fast pace.

Made in China 2025 is just the first phase of a grand three phase plan. The aim is to make China a powerhouse of world class manufacturing moving it from the current status of grand production workshop of the world. Focus is to improve quality of products and develop Chinese brand that are capable of competing companies on a higher level of product quality. China also want to develop highly sophisticated and cutting-edge next generation technologies. The country wants to research into new materials and become a key parts and component supplier for major products.

The economic reforms in China has always been on a step by step approach and implementation process is how the country anticipates the change extended over three phases [90]. Phase one to cover between 2016-2025. During this phase China wants to be among the global manufacturing powerhouses. During phase two which will be from 2026-2035, China plans to rise to the medium level of worlds manufacturing power camp. At the 100th anniversary celebration of the Chinese government which coincides with the third phase 2036-2049 is when the country dreams to be the world leading manufacturing power.

The country has a vast experience in implementing national strategic plans. During the 1978 reforms for economy, Shenzhen was chosen as a pilot city and turned into a Special Economic Zone. Free market business models were experimented, state planning and subsidiary policies were devised. Tax benefits were given to foreign firms who were interested in doing business in China [94]. The same approach is applied today with Ningbo, a port city, for the Made in China 2025 program. The plan is to speed up the capability for the city to construct new industrial and manufacturing setups, collaborate with local and regional innovation leaders, personnel training systems and policy that supports and enhance the fast development of the city. At the same time there is also focus on having an eco-friendly environment and to achieve diversity in development. In second phase, up to 30 cities might be selected for this program [95].

Table 9 Comparison of Industry 4.0 and Made in China 2025 [92]

	Germany	**China**
Issue Time	April 2013	May 2025
Aim	Intelligent manufacturing, cyber physical system, i-e applying the tools of ICT to production	From Made in China to Designed in China, make China's manufacturing strong and innovative
GDP (in year 2015)	\$3.363 trillion	\$11.007 trillion
Industry, value added (% of GDP in 2015)	30.95%	40.92%
Change of GDP 2007 - 2015	-2.25%	209.89%
Current well-known Industry	Volkswagen, Daimler, BMW, Siemens, Deutche Bank, Allianz	New energy, bridges, aerospace equipment, e-business, transportation network

Strength	Well established brands, global reputation of its products	Innovation driven, emphasize quality over quantity, green development, restructuring Chinese manufacturing industries
Implementation Period	10-15 years	10 years, extended to 2049
Implementation Phase	Not clearly explained	Three phases
Pilot Plan	N/A	City of Ning Po (1st pilot city)

4.1.2 Japan

Japan has been the birthplace for several manufacturing techniques that had been utilized and recognized worldwide [96]. Today the country is at a position where it can enter the next generation of smart industrial manufacturing. Japan has a great advantage due to its world class leading position in industrial robotics and IOT usage. Despite all the favorable situation and an edge over other economies around the world, Japan is still lagging behind USA and Germany in the implementation of smart manufacturing techniques [97]. The reason is a fact that Japanese companies have a strong belief in connected manufacturing and consider it as a major strength for their competitiveness across the globe.

Due to the current wave of change in ways where major manufacturing countries are looking to renew methods, the Japanese government has also realized the urgent need to give a boost to the manufacturing industry. It want to find solutions which is smart and sustainable as a society for future generation involving care for the senior citizen. The country doesn't plan to simply renew the manufacturing structure but rather the whole structure of the nation. The Japanese Ministry of Economy, Trade and Industry has advised to the local companies to introduce digitalization into their manufacturing, especially to help raise the SME into the age of smart manufacturing [98].

The key factors for success are very different in Japan compared to the industries in the western world. The focus here is the organizational issues, and the decision on how to make the manufacturing system more connected and pushed to lower levels of organization.

National Initiative 1: Robot Revolution Initiative

In 2014 the Government of Japan revised a strategy to realize a new industrial revolution driven by Robots. This led to the launch of Robot Revolution Realization Council [99]. Till recently it was the main strategic drive for industrial revolution and was linked to activities associated with Robot Revolution Initiative (RRI).

There were three major focused areas with the third as a major concern associated with IOT for manufacturing industry [100]. The purpose of the initiative is to assemble those who are most aware of problems associated, this includes the networking companies, industries where there is a strong need of control equipment's, IT and software vendors and other business organizations.

There are two points of concerns that are addressed through this initiative [96]:

- Knowledge sharing by those who have developed a practical use of IoT
- Deepening of the understanding associated with the merits of IoT Application

National Initiative 2: Society 5.0

Society 5.0 is a bigger vision of Japan which goes beyond the idea of Industry 4.0 [101]. It is related to a human-centered society where economic balance and advancement is reached with resolution of the social problem through a system that makes an integration between cyber and physical space.

The idea was first proposed in the fifth Science and Technology Basic plan. Later a move was established through Japan's Growth Strategy 2017, laid out by the Prime Minister's Office in June as a blueprint to Society 5.0, which discussed the integration of cutting-edge smart technologies for solving economic and social problems of Japan [102].

During the event at CeBIT 2017, "Society 5.0 – Another Perspective", the roadmap was presented by the Prime Minister of Japan for a need of super smart society with major roles for the next generation technologies in areas of IoT, AI, CPS, VR, Big Data and many more [102].

Society 5.0 comes at a point when the Japanese population is becoming more aged. While old age is not a factor of major problem but there are many challenges associated with it on multiple level and hence technology needs to be reshaped quickly to introduce smart technology and move society towards smart people.

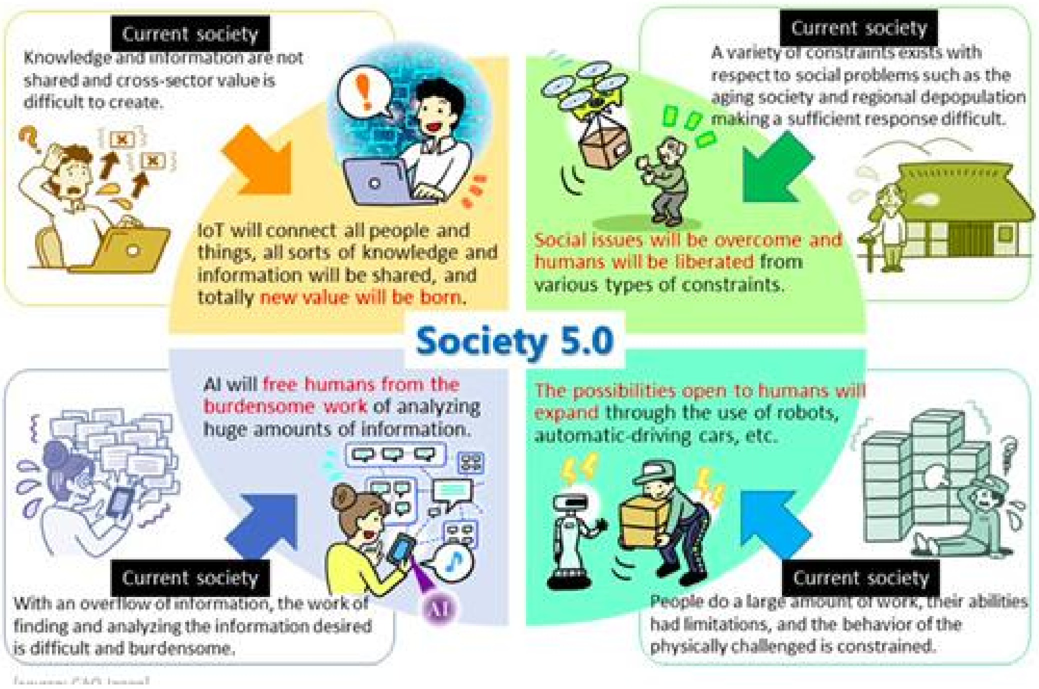


Figure 87 How will Society 5.0 affect the lives of us? [103]

Society 5.0 is a way to merge the differences and bring the cyberspace and physical space together. According to Society 5.0, the past society (Society 4.0) was based on cloud services to access data as in cyberspace via internet and then retrieve and analyze the information [103]. In Society 5.0, information and data will be collected through different kinds of sensors in the physical space and then this data will be accumulated in the cyberspace. This huge data (big data) will then be analyzed through AI and results will be fed back into the physical space resulting in intelligent decisions made.

This whole process will connect people, things and the cyberspace to optimize and deliver best results for any situation using a much intelligent AI solution which would far exceed the human capabilities. A new value will be brought to society and the industry structure in a way that was not possible before [104].

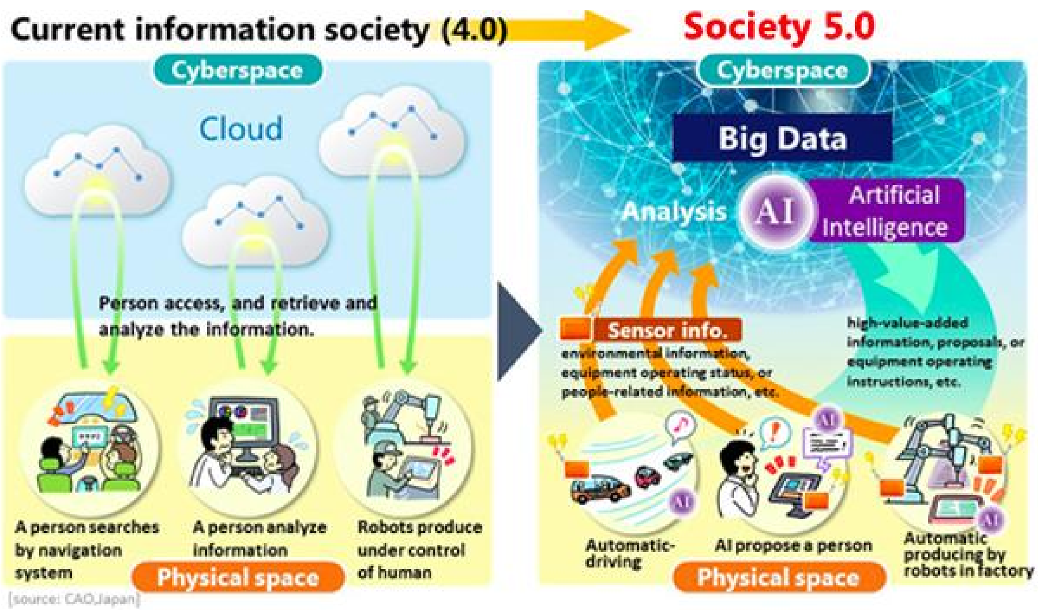


Figure 88 From Society 4.0 to 5.0 [103]

For Japan the digitalization is no more associated with manufacturing but rather across all the levels of society and to seek a future proof where economy is not limited by labor shortage or aging workforce. Society 5.0 will carry a major lesson for other nations to follow a similar idea and change.

4.1.3 USA

As the vision for a smart factory is becoming closer every day due to advancement in technology, the future for the manufacturing industries in the US will now depend on how the industrial leadership and economic developers play their card for the successful revival of US as the champion of world manufacturing. The US giants need to work on topics of automation, robotics, data and 3D printing while keeping in mind the value of human capital.

It is still a long way to a human less warehouse or factories but there are steps that needs to be taken towards more sophisticated, smartly automated processes which are becoming standard in many countries like Germany, Japan as important economic growth.

“Industry 4.0 is a wonderful opportunity for the American manufacturing when thinking about very skilled position pouring back into the economy”, says Aeron Ahlburnm MD of Industrial and Logistic Research, JLL [105]. Many industrial processes can now work much better if paired with intelligent structure and consider that USA has a vast pool of tech savvy and innovative minded people.

The US manufacturing sector currently stands as second largest in the world, only lagging begin China [106]. As per WEF report of 2018, US is renewed globally for its faster ability to innovate and is mainly at forefront of innovation and major development surrounding the next generation technologies necessary for Industry 4.0.

Innovation has always been a major strength of US. After all it was the birthplace of a movable assembly line [105]. According to the report by Congressional Research Service, automation technology is well routed in the manufacturing sector with only two out of five employees directly engaged in production.

The main challenge for the US is to maintain a momentum of innovation while working on improving productivity. Adoption of new technologies need to pick up pace and only then the innovation and productivity together will give a major boost to the US economy, says Ahlburn [107]. U.S manufactures need to invest heavily in advanced technologies to have a vast playing field to compete with the rest of the world powers. If there is no clear roadmap, the U.S manufacturing could collapse further and might face difficulties to regain its economic strength.

To pursue a powerful position, the country will need to establish strong presence in those market segments where the skillful talent is easy to find, specifically which are technological and innovation hubs such as California's Bay area, Boston, Austin Denver – just to name a few. Technology and research are already growing and well mature in the culture of this society. It is still a reality that smart factories will initially be dependent on strong skillful and significant human involvement.

National Initiatives

Industrial Internet Consortium

In March 2014 the Industrial Internet Consortium (IIC) was founded in the USA. More than 100 companies are participating in this program, like General Electric, IBM, Intel, AT&T and Cisco, to work on the technology of the future [108]. Also, important German companies are participating at the consortium, like Siemens and Bosch. Since many IT companies are included, the focus is on IoT and the interconnection of future factories. The vision of IIC is similar with the goal of Industry 4.0. Production should be more efficient and value-added processes should be optimized. Furthermore, the companies want a higher availability of the machines as well as a high level of individualized production.

Smart Manufacturing Leadership Coalition

In June 2016, the Obama administration announced a selection of Smart Manufacturing Leadership Coalition in order to initiate a public-private partnership [109]. This partnership was aimed at applied research and development with focus on smart manufacturing technologies.

The Smart Manufacturing Innovation (SMI) Institute which is supported by the Advanced Manufacturing Office had been expected to bring more than $140 million in public-private investments and bringing together a consortium of almost 200 partners [111]. These partners come from different walks of life including academia, non-profiles and industries with a unified goal to move towards energy efficiency and increased production capabilities of US manufactures.

SMI Institute is part of a broader network established by the government, called National Network for Manufacturing Innovation. It is a cross government to create a collaboration between nine institutes. NNMI is supported through a $600 million in investments from the Federal Government and approximately $1.2 million in reinvestments coming from non-federal resources such as industries, academies and state governments [110]. The aim is to speed up the R&D process and deploy broadly applicable technologies to make the industrial manufacturing sector competitive.

4.2 Overview of the Analysis

Following table is a summarized analysis of non-EU countries and compared with one another on their featured element in every tool used and targets achieved. They are also compared with EU country to deduce general comments.

Table 10 Summarized Table comparing non-EU countries and EU as a whole

	China	Japan	USA	EU	General Comment
Development Program	Made in China 2025	Society 5.0	Smart Manufacturing Leadership Coalation	Horizon 2020	
Size of Industry	251-5000	300+	1-250	1 - 250	In EU the power lies mostly in Startups, while in non-EU majority of the interest remains in middle and well-established firms.
Type of Industry Sector	Telecommunication	Manufacturing & Production	Automation & Manufacturing	Manufacturing & Production	Manufacturing in general is the most common industry that is focused towards new technology
Domain of Customization	Integration	Software	Integration	Integration	Every country that moves towards digitalization must have hardware involved with software and IOT and hence integration is

					found as prominent domain of customization
Technological Tools	IOT	IOT/Big Data	IOT	Major I4.0 Tools	While in EU focus lies on I4.0 tools, non-EU countries focus mostly on IOT
CPPS	8%	-	6%	7.3%	CPPS is not well sought out tool yet in the industry across all countries
Non-Technological Tools	Strategic & Business Tools	Strategic & Business /Educational Tools	Educational Tools	Educational Tools	Educational tool is important to develop highly skilled workforce for the future jobs.
Smart Systems	Smart Technology	Smart Sensor	Smart Sensors	Smart Technolgy	Smart technology is utilized almost everywhere for innovative methods
Communication Network	Cloud	Wireless	Cloud	Cloud	Digitalization can be only seen fully accomplished when cloud computing is preferred way of communication
Major I4.0 Projects	AI	Automation	AI	Automation	While Automation is focused in EU, AI is big focus in USA and China to dominate each other in economically and globally
Targets	Operational Targets	Operational Targets	Operational Targets	Operational Targets	Every country has some operational targets
Operational Targets	Real Time	Optimization	Real Time	Efficiency	While efficiency is sort out more in EU, real time control is more prominent in USA and China in order to work on big data.
Environmental Control	Smart Energy Consumption	Smart Energy Consumption	Smart Energy Consumption/Sustainability	Smart Energy Consumption	Environmental control is still very low in every country and no major efforts are made in this regard
Communication	Data Sharing	Data Sharing	Data Sharing	Data Sharing	For a future connected industry data sharing is crucial

Adaptability	Flexibility	Flexibility	Flexibility	Flexibility	Majority of projects are flexible enough to be utilized for multiple purposes

This table is also an overview of all the above elements that were studied for every non-EU country individually:

1. Domain of Customization
2. Size and type of Industry
3. Technical and non-technical tools
4. Targets

The following are the major differences being observed between the non-EU countries and a comparison drawn with EU:

1. **Majority of attention for new technologies across non-EU comes from middle class:** While the majority of projects studied from European countries, many projects were carried out by small industries or startups but in American, China and Japan it is the medium sized industries which are taking a lead.

2. **Manufacturing and production a major drive:** Most of the projects around the world are being considerably across manufacturing and production companies. In China the focus is from telecommunication where particularly companies like Huawei, Xiaomi and several other part suppliers are investing into new research

3. **Integration as a preferred domain:** Every country that moves towards digitalization must have hardware involved with software and IOT and hence integration is found as prominent domain of customization.

4. **Assessing technical and non-technical tools:** IOT is the main technical tool being researched or implemented around projects. In EU the most focused area was related to Automation and Robotics. There is a much higher lack of interest in CPPS outside EU. It is expected that with a progress in Society 5.0 by Japan, a strong wave of CPPS projects might emerge. Cloud computing is also a preferred way of communication in non-EU countries. Both China and America who are competing against each other for economic power are also competing on AI technology.

5. **Targets:** Efficiency was the major target in EU but in China and USA the focus lies on real time. It allows to collect massive data for further improvement in systems and for AI related technology. In Japan with had been very advance in technology related to robotics and automation is more

focused on optimizing its processes. Flexibility of projects also exist here, and data sharing is more easily possible in these countries due to less strict policies of the government.

Chapter 5

Conclusion & Future Perspective

5.1 Conclusion

Over the last 20 years the industrial footprint has changed dramatically. In the 90's the manufacturing values were about €3,451 billion. 60% of this value was linked to only six major nations i-e UK, Germany, Japan, Italy, France and US. Emerging economies only contributed to 21%. Over the time there has been a decline in manufacturing value from western countries. EU has lost a lot of manufacturing economy over the past two decades. The new Industrial revolution is now again breathing new air in the Eurozone. It is expected that with positive steps the industrial share of EU can rise to 20%.

Industrial Internet of things (IIOT) which is one of the bases to Industry 4.0 is gaining grounds across the globe. The main idea of IIOT is to improve the production capacity and improve the efficiency of operating an industry, and it is expected to bring significant impact on the world economy. GDPR is another important issue that can put off some companies but with right tools and understanding they can study their current structure and process. They can understand how data is processed, where it is stored and regularize the flow of data within its system.

Western world had already faced three revolutions which resulted in disruptive technology and significantly higher productivity. Fourth revolution, known as the Industry 4.0, is already on its way and it comes with answer to challenges faced by major economies today. Industry 4.0 is penetrating across the social, economic and political landscape. Due to globalization of economies many countries are trying to position themselves in the global market. Study conducted for EU countries of Germany, Italy, France and Spain. Non-EU countries such as China, Japan and USA revealed that despite the concept being new there has been successful implementation of projects in these countries. Developed countries are indeed on the forefront. EU is leading under combined banner through programs funder under Horizon 2020 project while also individual countries are shaping their own strategy towards achieving goals.

All the above-mentioned countries were studied in this research for their role in achieving target towards smart manufacturing and implementing Industry 4.0. However, to compare and analyse in a quantitative way and to understand the results of practical implementation of these programs 259 projects in combine were studied. Various analysis was conducted for each of these projects. A comparison was drawn between EU countries and Non-EU countries.

Germany had been the main player behind this revolution where companies are working on various projects and government institutes. More than 300 players from 159 organizations are actively working on Industrie 4.0 and this number is expanding massively. The main focused area is manufacturing and production while the research on cyber physical systems is highest compared to all studied countries. Education tool is also something more common in Germany then in other countries. The country is using smart technology and focused more on automation.

France has gone through a cycle of progress. Starting in 2013 with La Nuovelle France Industrielle, it gained more interest towards reviving its industry through Industrie du Futur in 2015. Recently in 2017 the administration launched the program of French Fab. This initiative aims to promote French manufacturing export and market share and is focused on driving French industrial base that relies on medium sized firms that exports to outside markets. In March 2018, France also unveiled its commitment to spend €1.5 billion over next four years on AI which is a big commitment compared to other EU countries. Through the analysis conducted, the country is focused mostly on automation and manufacturing with robotics used as a major tool of technology. One major drawback is that the country is lagging behind others in term of CPPS.

Digital transformation is a priority for the Spanish industry and many stakeholders are working together to push for a common goal in Industry 4.0; hence making an urgency in the market. Connected Industry 4.0 is the main initiative and part of the Spanish Digital Agenda which is meant to strengthen the industrial sector. The General Secretariat of Industry and SME under the Ministry of Economy Industry and Competitiveness launched this initiative in 2015. The projects studied reveals that majority of work in Spain is focused on training, research and development. Many universities and research centers are involved particularly from the Catalonia region. There is also a slow initiation of research in the field of CPPS. AI is one of the major tools used and blockchain and cloud computing is getting higher priority in the country compared to other EU countries.

In February 2017 The Italian government adopted the National Plan for Industry 4.0. The new strategy, planned initially for a period of 2017-2020, encourages investment in new technology, R&D projects and elevate the completeness of the manufacturing industries. To this end, the government plans to spend about €18 billion over the planned period. Majority of incentive given are fiscal and related to tax cuts for companies of various sizes. An important public partnership has recently taken a practical shape in the form of a competence center called MADE by Politecnico Di Milano in collaboration with Comau where €22 million investment has been planned over the next 3 years. If we look at our analysis conducted, the companies more interested in innovation are related to manufacturing and production with 9% projects currently working around CPPS second just to Germany. Cloud computing is also on a rise and automation is one of the most important tools used. While the country is on a rise, there is more need for private investment and banks needs to make loan easily accessible.

UK is going through a growing curve for disruption of technology. According to a recent survey by KPMG UK, about 56% of people consider I4.0 as a huge opportunity to reshape UK manufacturing. Midsize companies are more optimistic compared to large enterprises. Brexit is currently considered a game changer for UK in terms of economy. 45% of manufacturers consider a hard Brexit as having negative impact. Last year Theresa May government launched Industrial Strategy in order to revive the industrial sector and boost the productivity, earning power and quality of life. The strategy involves huge government investment in R&D projects, reforming education systems and supporting businesses across the country. While conducting the survey, there were not many case study examples for UK manufacturing. Majority of these projects studied were from manufacturing and production industry. Smart technology is extensively used by companies and automation and robotics remains a focused area.

China rose to dominance by the end of 20th century when globalization was in full swing. This led to Made in China products which today can be found everywhere on the planet. The traditional approach once key to success is slowly diminishing and China has realized the urgent need to restructure its approach from quantity to quality. The government has a particular interest where they launched Made in China 2025 project in 2015. It is a three-phase program where the strength will lie in innovation, quality and green development. Chinese firms are slowly rising with many firms acquiring western companies like KUKU robotics. The Chinese manufacturers are highly focused on AI with telecommunication industries leading the R&D sector and using IOT tools extensively. Cloud is also explored more in China due to less regulatory laws. 8% of the studied projects are also focused on CPPS.

Japan had been the birthplace for several manufacturing techniques which are recognized and utilized worldwide. It is one of the few countries which had taken great advances in Automation and robotics and its implementation across different sectors. Its unique position and experience give the country an edge to enter the new era of technology more quickly and in better ways. Considering this, the Japanese administration looks at the progress as a whole community and launched a new program called Society 5.0 which is rather beyond Industry 4.0 and has a much wider scope that involves the whole society. Digitalization is what the country wants to achieve across all levels of society and seek a future proof where economy is not limited by its aging workforce. According to my research the industrial focus remains mostly under manufacturing and production with IOT and big data as strong tools. Automation is also important and rather heavily deployed in majority of Japanese manufacturing industries. There was no prominent record found regarding CPPS which is something the country needs to explore.

Innovation had been a major strength of USA and automation technology is well rooted in the manufacturing sector. Currently the main challenge for the country is to improve innovation but at the same time grow up the productivity. The country needs to focus on establishing strong productive position in market segment where the skills are high, and talent is easy to find such as Boston or California Bay area. The first main interest by government and industries was seen around March 2014 when the Industrial Internet Consortium was founded involving 100 companies like General Electric, IBM, Intel etc. The main focus was around IOT and interconnected network for future factories. In June 2016 Obama administration showed a more solid approach with forming Smart Manufacturing Leadership Coalition. Another institute called the smart Manufacturing Innovation Institute is expected to bring more than $140 million in public-private investments and bringing together a consortium of almost 200 partners. R&D is also a focused area and applied research is gaining strength under various programs initiated. As per the analysis conducted automation and manufacturing is more focused on new technology with AI as a major tool being explored.

After individual study of every country. A combined analysis was also done for EU and non-EU. In EU majority of the attention towards new technology and innovation is coming from startups or small companies. These companies are readier to introduce disruptive technologies in order to increase their market share. Manufacturing and production industry are a major drive for innovation across the studied countries. This is due to the powerful impact it can have on economy. Integration is a preferred domain of customization, apart from France where the country is more focused on hardware customization. This is because the country is majorly investing in introducing robotics and automation machines more prominently. While Germany is focused on smart technology, the other countries are focused on automation, robotics, VR and AI. CPPS is more focused in Germany followed by Italy yet it is still unexplored the way it should be. Cloud computing is gaining momentum across all the EU countries and education tools are also a focus.

Efficiency is one of the major targets set by all the EU countries. Efficiency can benefit productivity, cost and time. There is a lack in progress towards communication where data collection and sharing is important towards achieving higher goals in I4.0. Changes in certain government law might help countries to research deeper into this concept. Most of the project studied were all flexible enough to be implemented in different ways.

In non-EU countries majority of the projects came from the medium size companies. Similar to EU, the major drive is from manufacturing and production industries. Integration is a preferred domain with IOT as a strong focus in terms of technical tools. There is a lack of interest for CPPS. Cloud computing and AI are a strong component of change due to more relaxed data laws. In China and USA the major target is to involve real time data collection into projects. Japan is already ahead in terms of technology and hence more focused on optimization of the current processes. Most of the projects studied were indeed flexible.

This thesis has reviewed and reported the current and present state of Industry 4.0 and its projects across major economies of the world. Suggestions had been highlighted and future perspective and goals for these countries towards a smart industry. In the next topic a broader view is given for future.

5.2 Future Perspective

Digitalization ought to have a powerful impact on the control and operations of manufacturing industries across the globe. It is on verge of becoming a growing academic field and research area and will prove to be the business differentiator for future. In the near future we could observe a major shift towards open architecture and multivariable control. There would be more integrated and connected industries compared to isolated structures. Automation, Robotics will mature further and involve more human machine collaborative robots. AI is also becoming a major research field and it is expected to bring massive breakthroughs towards easy and quick implementation of AI across the globe. America and China might take lead in AI but China is expected to powerfully go ahead of any country over the next few years in terms of AI. CPPS is very rarely explored and in early phase of research across many countries. Germany is investing a lot followed by China. CPPS is the most powerful tool for converting industries into smart industries. Once the technology is developed further, it is expected to bring massive changes to the industrial structure immediately. Virtual commissioning of technology will be applied even further as a result.

While there are infinite possibilities expected with fourth industrial revolution, yet this future technology also poses a threat to almost five million workers who could lose job as a result. Outdated technology might be quickly stopped as they will lack quality and production while resulting in inefficiency and higher cost.

According to Mr. Warren G. Bennis, “In future the factories will have two employees: a human and a dog. Human task will be to feed the dog and dog will prevent human from touching the smart automated system” [112].

Having said this, the issue of unemployment can be partially justified as automation and smart technology ultimately means fewer human resources needed but at the same time companies will need an increasing number of highly skilled and specialist workforce. Therefore, while the technology is being explored, it is important that the governments invest in developing educational program and social policies towards high skill education on a priority basis.

Another aspect that governments need to investigate is modernization of laws and strengthening partnership with private businesses. If an attractive atmosphere is created, then huge investment can be seen by private businesses towards financing research studies and more public private partnerships can work out like the one in Italy; MOVE.

Standardization of technology can prove a very powerful point for Europe as a whole. A standardized approach can create more opportunities for joint projects and further progress collectively as a block.

EU will also need to draw changes or alteration to its data law which is a hinderance in progress towards a stronger digitalized industrial network as many big corporations and those industries which involves a lot of data related documents prevent from investing into digitalization to prevent any kind of risk.

Having said that the future is very positive towards Industry 4.0. There are problems which needs to be addressed but with a solid strategy any country can reap benefit for its economic uplift. It is also time EU countries take strong position if it wants to regain its lost manufacturing income.

Bibliography

1. O'Sullivan, F. *What Is the Internet of Things?* 2018.
2. J. Wan, D.Z., Y. Sun, K. Lin, C. Zou, and H. Cai, *VCMIA: A novel architecture for integrating vehicular cyber-physical systems and mobilecloud computing.* Mobile Netw. Appl., 2014. **19**(2): p. 153-160.
3. J. Wan, H.Y., D. Li, K. Zhou, and L. Zeng, *Cyber-physical systemsfor optimal energy management scheme of autonomous electric vehicle.* Comput. J., 2013. **56**(8): p. 947-956.
4. F. Li, J.W., P. Zhang, D. Li, D. Zhang, and K. Zhou, *Usage-specic semantic integration for cyber-physical robot systems.* ACM Trans. Embedded Comput. Syst., 2016. **15**(3).
5. M. Brettel, N.F., M. Keller, and M. Rosenberg,, *How virtualization, decentralization and network building change the manufacturing landscape: An industry 4.0 perspective.* Int. J. Mech., Ind. Sci. Eng, 2014. **8**(1): p. 37-44.
6. Health, P., *Pillo: Your Personal Home Health Robot*. 2016.
7. Ibarra, D., J. Ganzarain, and J.I.J.P.M. Igartua, *Business model innovation through Industry 4.0: A review.* 2018. **22**: p. 4-10.
8. Burns, E., *Internet of a billion things: Capturing IIoT innovation*. 2015: CBR Online.
9. Paul Daugherty, P.B., Walid Negm, Allan E. Alter, *Driving Unconventional Growth through the Industrial Internet of Things*. 2015, Accenture Technology.
10. Knowledge@Wharton. *Big Data and Energy: A Clear Synergy* ; Available from: http://knowledge.wharton.upenn.edu/article/the-big-data-and-energy-synergy/
11. Day, S., *The Rise of the Ultra-Miniature Magnetic Reed Switch*

    . 2013, EECatalog: Embedded Systems Engineering.
12. Eric Knorr, G.G., *What Cloud Computing Really Means*. 2008, Sky Solutions.
13. Technopedia, *Big Data*
14. Marta Götz, B.J., *Clusters and Industry 4.0 – do they fit together?* European Planning Studies, 2017. **25**(9): p. 1633-1553.
15. Heiner Lasi, P.F., Thomas Feld, Michael Hoffmann, *Industry 4.0.* Business & Information Systems Engineering, 2014. **6**(4): p. 239-242.
16. Forschung, B.f.r.B.u., *Zukunftsbild „Industrie 4.0.* Bonn: Bundesministerium für Bildung und Forschung, 2013.
17. Ayşe Göksu Özüdoğru, E.E.n., Djihane Ammari, *HOW INDUSTRY 4.0 CHANGES BUSINESS : A COMMERCIAL PERSPECTIVE.* International Journal of Commerce and Finance, 2018. **4**(1): p. 84-95.

18. Chen, B., et al., *Smart Factory of Industry 4.0: Key Technologies, Application Case, and Challenges.* 2018. **6**: p. 6505-6519.

19. Group, S.-G.E.W., *Alignment Report forReference Architectural Model for Industrie 4.0/ Intelligent Manufacturing System Architecture*. 2018, Sino-German Industrie 4.0/Intelligent Manufacturing Standardisation Sub-Working Group.

20. Factory, D., *Product lifecycle management in industry 4.0*, in *Hannover Messe* 2016.

21. P., R., *Industry 4.0 and GDPR, friends or unacquainted?*, in *LinkedIn*. 2017.

22. Hub, B., *GDPR deep dive—how to implement the 'right to be forgotten'*. 2017.

23. Leeson, T., *GDPR in manufacturing: Where to start, threats and opportunities*, in *Opentext Blog*. 2018.

24. Fuchs, C.J.t.C., Capitalism and C.O.A.J.f.a.G.S.I. Society, *Industry 4.0: The Digital German Ideology.* 2018. **16**(1): p. 280-289.

25. Commission, E. *What is Horizon 2020?* ; Available from: ec.europa.eu/programmes/horizon2020/en/what-horizon-2020.

26. Daniel Buhr and Thomas Stehnken INDUSTRY 4.0 AND EUROPEAN INNOVATION POLICY, 2018

27. Commission, E. *EU businesses go digital:Opportunities, outcomes and uptake.* 2018

28. Towards Industry 4.0: an overview of European Strategic Roadmap, C. Santos, June 2017

29. EPoSS, "Strategic Research Agenda of the European Technology Platform on Smart Systems Integration" Berlin, 2009

30. EPoSS, "Strategic Research Agenda of the European Technology Platform on Smart Systems Integration" Berlin, 2017.

31. EFFRA, "Factories of the future strategic multi-annual roadmap," Brussels, 2010.

32. EFFRA, "Factories of the Future: Multi-annual roadmap for the contractual PPP under Horizon 2020," Brussels, 2013.

33. M.P.H.L. Group, "Manufuture - Strategic Research Agenda" Brussels, 2006.

34. A. De Saint-exupery. Internet of Things: Strategic Research Roadmap. Internet Things Strateg. Res. Roadmap, (2009) 1–50.

35. B. Schätz, M. Törngren, S. Bensalem, M.V. Cengarle, H. Pfeifer, J. McDermid, R. Passerone, Alberto, Sangiovanni-Vincentelli, "CyPhERS: Cyber-Physical European Roadmap & Strategy," Brussels, 2015

36. P. Lingman, J. Gustafsson, A.O. Johansson, O. Ventä, M. Vilkko, S. Saari, J. Tornberg, A. Siimes, "European Roadmap for Industrial Process Automation" 2013.

37. Towards an Industrial Renaissance

38. EFFRA, "*Factories 4.0 and Beyond",* Recommendations for the work programme 18-19-20 of the FoF PPP under Horizon 2020, 2016.

39. "High-Tech Strategy 2020." Federal Ministry of Education and Research, 2010.
40. B. E. d. Industry, "Implementation of an Industry 4.0 Strategy - The German Plattform Industrie 4.0," 2017. [Online].
41. B. M. (. E. C. (. U. L. (. R. N. Shi-Wan Lin (Thingswise), "Architecture Alignment and Interoperability," Platform Industrie 4.0, 2017.
42. D. u. V. DIN, "GERMAN STANDARDIZATION ROADMAP - Industry 4.0," DIN e.V, 2018.
43. D. T. Monitor, "Germany: Industrie 4.0," European Commission, 2017.
44. "Midsize sector transfer," Plattform Industrie 4.0, [Online]. Available: https://www.plattformi40.de/I40/Navigation/EN/InPractice/TransferSMEs/transfer-smes.html.
45. M. G. Institute, "WHAT’S NOW AND NEXT IN ANALYTICS,AI, AND AUTOMATION," Mckinsey&Company, 2017.
46. Wikipedia, "Economy of Germany," [Online]. Available: en.wikipedia.org/wiki/Economy_of_Germany.
47. C. Adams, "Estonia, A Blockchain Model For Other Countries?," Invest in Blockchain, Jan 2018. [Online]. Available: www.investinblockchain.com/estonia-blockchain-model/.
48. "eGovernment in Germany," European Commission, 2016.
49. I. K. DAVID KORENKE, "Blockchain in Government: Is Germany Falling Behind?," The Governance Post, Nov 2017. [Online]. Available: www.hertie-school.org/the-governance-post/2017/11/blockchain-government-germany-falling-behind/.
50. J. DELCKER, "Germany’s €3B plan to become an AI powerhouse," Politico, Nov 2018. [Online]. Available: www.politico.eu/article/germanys-plan-to-become-an-ai-powerhouse/
51. A. Sullivan, "AI: Government pledges billions aimed at bringing Germany up to speed," Nov 2018. [Online]. Available: www.dw.com/en/ai-government-pledges-billions-aimed-at-bringing-germany-up-to-speed/a-46296320.
52. "MEASURE PERFORMANCE AND SET TARGETS," [Online]. Available: www.infoentrepreneurs.org/en/guides/measure-performance-and-set-targets/
53. "Adaptability,"Wikipedia,[Online].Available:en.wikipedia.org/wiki/Adaptability.
54. " Impact of Business and Industry on the Environment," Israel Ministry for Environmental Protection, [Online]. Available: http://www.sviva.gov.il/English/env_topics/IndustryAndBusinessLicensing/Pages/EnvironmentalImpactOfBusiness.aspx.
55. IMF Country Report No. 17/288, France, Sept 2017
56. "UNIDO Statistics Data Portal," [Online]. Available: stat.unido.org/country-profile/economics/FRA.
57. "World Bank Data," [Online]. Available: data.worldbank.org/country/france?view=chart.
58. B. Research, "France Country Risk Report," 2018.

59. B. A.-O. ,. M. S. D. W. Dr. Anil Khurana, "The Future of Manufacturing - France," PWC, 2018.
60. B. E. d. Industry, "Implementation of an Industry 4.0 Strategy - The German Plattform Industrie 4.0," 2017. [Online]
61. D. Communication, "The French Fab," Business France, Feb 2018. [Online]. Available: www.businessfrance.fr/procom-discover-france-news.
62. J. Y, "Why France's Crypto Market is Stagnating Despite Promising Efforts From Gov't," Crypto me now, Jan 2019. [Online]. Available: cryptomenow.com/why-frances-crypto-market-is-stagnating-despite-promising-efforts-from-govt/.
63. C. KARLSSON, "DIGITAL TRANSFORMATION IN THE SPANISH INDUSTRY," BUSINESS SWEDEN IBERIA, 2017
64. "Economy of Spain," Wikipedia, [Online]. Available: en.wikipedia.org/wiki/Economy_of_Spain.
65. O. Lazaro, "Analysis of National Initiatives for Digitising Industry. Spain: Industria Conectada 4.0," European Commission, 2017.
66. "The Digital Economy and Society Index (DESI)," European Commission, 2019. [Online]. Available: ec.europa.eu/digital-single-market/en/desi.
67. "Spain: Industria Conectada 4.0," European Commission, 2017.
68. M. Ehrenfreund, "Researchers have a new theory for why companies are sitting on ungodly piles of cash," Washington Post, July 2017. [Online]. Available: www.washingtonpost.com/news/wonk/wp/2017/07/18/researchers-have-a-new-theory-for-why-companies-are-sitting-on-ungodly-piles-of-cash/?utm_term=.084210297480
69. J. S. Hugo Sarrazin, "Competing in a digital world: Four lessons from the software industry," Mckinsey, Feb 2013. [Online]. Available: www.mckinsey.com/business-functions/digital-mckinsey/our-insights/competing-in-a-digital-world-four-lessons-from-the-software-industry.
70. M. Vega, "Digital transformation: The importance of integration," Belatrix, Oct 2017. [Online]. Available: www.belatrixsf.com/blog/digital-transformation-importance-integration/.
71. "SPAIN – MORE THAN HALF OF WORKERS BELIEVE THAT AI IS A POSITIVE OPPORTUNITY FOR THEIR ROLE," SIA, Jan 2019. [Online].
72. G. Thomas, "Spain: Environmental Issues, Policies and Clean Technology," AZO Cleantech, July 2018. [Online]. Available: www.azocleantech.com/article.aspx?ArticleID=281.
73. C. Terenzi, "Blockchain Technology Usage Increases in Spain," Sep 2018. [Online]. Available: www.coinstaker.com/spain-works-with-blockchain-technology/
74. "Economy of Italy," Wikipedia, [Online]. Available: en.wikipedia.org/wiki/Economy_of_Italy.
75. "Welcome to the U.S. Commercial Service in Italy," Export.Gov, 2017. [Online]. Available: 2016.export.gov/italy/.

76. D. T. Monitor, "National initiatives," European Commission, [Online]. Available: ec.europa.eu/growth/toolsdatabases/dem/monitor/category/national-initiatives.
77. P. Dario, Industry 4.0 and Factory of the Future initiatives in Europe: focus on Italy, The Biorobotics Institute Sant'Anna, 2017
78. S. Neil, "Italy's Industria 4.0 Transformation," Automation World, Jan 2019. [Online]. Available: www.automationworld.com/italys-industria-40-transformation
79. "LAUNCH OF MADE COMPETENCE CENTER," Politecnico Di Milano, 2019. [Online]. Available: www.polimi.it/en/opening-details/article/10/nasce-il-competence-center-made-6289/.
80. "Hyperlean will be inside in the Competence Center MADE at the Polytechnic of Milan - Hyperlean," Hyperlean, [Online]
81. UNESCO,Oct2016.[Online]. Available: http://www.unesco.org/new/en/media-services/singleview/news/only_a_minority_of_innovative_firms_collaborate_with_univers.
82. B. Brett Smith, "Italy: Environmental Issues, Policies and Clean Technology," July2018.[Online].Available:www.azocleantech.com/article.aspx?ArticleID=536.
83. A. Seth, "The Importance of Flexibility in Agile Development," Clear Bridge Mobile, Mar 2016. [Online]. Available: clearbridgemobile.com/the-importance-of-flexibility-in-agile-development/.
84. "Rethink Manufacturing - Designing a UK Industrial Strategy for the age of Industry 4.0," KPMG, 2017.
85. "Industrial Strategy - Building a Britian fit for the future," HM Government, 2018
86. "United Kingdom Smart Sensors Market - By Type (Flow Sensors, Image Sensors, Pressure Sensors, Position Sensors, Motion and Occupancy Sensors, Light Sensors, Water Sensors), Technology, Trends, Forecast - (2017 - 2022)," Dec 2017. [Online]. Available: www.mordorintelligence.com/industry-reports/united-kingdom-smart-sensors-market-industry.
87. "UK falls behind in cloud computing adoption," HSo, [Online]. Available: www.hso.co.uk/leased-lines/technology-news/cloud-computing-news/uk-falls-behind-in-cloud-computing-adoption.
88. "Government launches world leading plan to tackle air pollution," Department for Environment, Food & Rural Affairs, Department of Health and Social Care, The Rt Hon Michael Gove MP, The Rt Hon Matt Hancock MP, Jan 2019. [Online]. Available: www.gov.uk/government/news/government-launches-world-leading-plan-to-tackle-air-pollution.
89. "China and the fourth industrial revolution," CHEUNG KONG Graduate school of Business, 2017.
90. J. W. Alice TSE, "Why 'Made in China 2025' triggered the wrath of President Trump," Sep 2018. [Online]. Available: multimedia.scmp.com/news/china/article/made-in-China-2025/index.html

91. X. Z. BIAN YONGZU, "From “Made in China” to “Intelligent Manufacturing from China”," Oct 2017. [Online]. Available: http://chinaindiadialogue.com/from-made-in-china-to-intelligent-manufacturing-from-china.

92. L. Li, "China's manufacturing locus in 2025: With a comparison of “Made-in-China," Technological Forecasting & Social Change, pp. 66-74, 2018.

93. State Council of People Republic of China, 2017. Building a World Manufacturing Powerpremier and ‘Made in China 2025’ Strategy, January 31, 2017. Retrieved on Feb 10

94. Li, L., 2013. The path to made-in-China: how it was done and future prospects. Int. J. Prod. Econ. 146 (1), 4–13.

95. ifeng.com, 2017. Made-in-China 2025 Pilot Cities Extended to 20 (中国制造2025试点城市 将扩围至20余个), 2017–01-12 07. Retrieved on Feb. 6, 2017. http://finance.ifeng. com/a/20170112/15139387_0.shtml.

96. P. Sund, "SEIZING INDUSTRY 4.0 OPPORTUNITIES IN JAPAN," Business Sweeden, 2017.

97. "The race towards Industry 4.0," MALAYSIA PRODUCTIVITY CORPORATION, 2018.

98. M. MATSUTANI, "Examining 'Industry 4.0' opportunities," The Japan Times, April 2016. [Online].

99. "About RRI (Robot Revolution Initiative)," [Online]. Available: www.jmfrri.gr.jp/english/outline/763.html.

100. *Establishment of RRI,* Robot Revolution & Industrial IoT Initiative, 2018.

101. "Toward realization of the new economy and society," Keidanren, 2016.

102. Keidanren, "From Industry 4.0 to Society 5.0: the big societal transformation plan of Japan," iScoop, 2017. [Online]. Available: www.i scoop.eu/industry-4-0-society-5-0/.

103. "Realizing Society 5.0," Japanese Government, [Online]. Available: www.japan.go.jp/abenomics/_userdata/abenomics/pdf/society_5.0.pdf.

104. N. Jao, "Never mind Industry 4.0 – Japan is planning for Society 5.0," Disruptive Asia, Sep 2017. [Online].

105. "How will Industry 4.0 impact U.S. manufacturing?," JLL USA, Jan 2018. [Online]. Available: www.us.jll.com/en/trends-and-insights/cities/will-industry-4-0-impact-us-manufacturing.

106. P. J. Petras, "China: Rise, Fall and Re-Emergence as a Global Power," Global Research - Center for Research on GLobalization, Dec 2018. [Online].

107. "How Will Industry 4.0 Impact U.S Manufacturing?," Mar 2018. [Online]. Available:www.augmate.io/how-will-industry-4-0-impact-u-s-manufacturing/.

108. "The “Industrial” Internet of Things and the Industrial Internet Consortium," Garrner, Mar 2014. [Online]. Available: blogs.gartner.com/earl-perkins/2014/03/28/the-industrial-internet-of-things-and-the-industrial-internet-consortium/.

109. "FACT SHEET: President Obama Announces Winner of New Smart Manufacturing Innovation Institute and New Manufacturing Hub Competitions," White House, June 2016. [Online]. Available: obamawhitehouse.archives.gov/the-press-office/2016/06/20/fact-sheet-president-obama-announces-winner-new-smart-manufacturing

110. "The Latest News About the US Manufacturing Network," Advanced Manufacturing Media, June 2014. [Online]. Available: advancedmanufacturing.org/latest-news-us-manufacturing-network/.

111. "Smart Manufacturing: Transforming American Manufacturing with Information Technology," Office of Energy Efficiency and Renewable Energy, June 2016. [Online]. Available: www.energy.gov/eere/amo/articles/smart-manufacturing-transforming-american-manufacturing-information-technology.

112. Michael Hattermann, Director Brussels, VATM e.V., No doubt about it: Industry 4.0 is needed to keep Germany competitive M2M Summit 2013, Düsseldorf, September 10, 2013, 31.03.2016.

Appendix 1

List of Projects in Germany

Title Of the project	Company Name	Type of Industry	Size of Industry
ARISO Contactless Connectivity Pilot Project	TE Connectivity	Telecommunication	15000+
Autonomous Floor Roller	Robert Bosch GmbH	Engineering & Electronics	15000+
Educational Chain to becoming a Cyber-Security Professional	Deutsche Telekom	Telecommunication	15000+
Learning factory an integral part of production	FESTO GmbH	Automation & Manufacturing	15000+
Integrated data management platform	Siemens AG	Manufacturing & Production	15000+
Maximum plant performance - with Smart Data	Siemens AG	Manufacturing & Production	15000+
Modular production line high pressure pump for direct injection	Robert Bosch GmbH	Engineering & Electronics	15000+
The Digital Factory	Siemens AG	Manufacturing & Production	15000+
The right methodology for the future	Siemens AG	Manufacturing & Production	15000+
Smart Operator	Innogy	Energy	15000+
Use of pick-by-vision solution xPick at Schnellecke Logistics in Wolfsburg	Schnellecke Logistics	Logistics	15000+
Visualization of the value stream	Robert Bosch GmbH	Engineering & Electronics	15000+
Hierarchical safety control	ABB Group	Automation & Manufacturing	5000-15000
Barrier-free assembly station	ABB Group	Automation & Manufacturing	5000-15000
Good training for everyone at the company	Robert Bosch GmbH	Engineering & Electronics	5000-15000
Field Device Integration (FDI) for Industry 4.0 field level	ABB Group	Automation & Manufacturing	5000-15000
KUKA roboter production Augsburg	KUKA Roboter GmbH	Automation & Manufacturing	5000-15000
Remote robot monitoring	ABB Group	Automation & Manufacturing	5000-15000
Smart alarm management	ABB Group	Automation & Manufacturing	5000-15000
Intelligent networking of human, machine and component	TRUMPF	Manufacturing & Production	5000-15000
Smart Products & Smart Processes	ACD Elektronik GmbH	Engineering & Electronics	251-5000
Bender final assembly plant	Bender GmbH	Engineering & Electronics	251-5000
Packaging lines in the age of Industry 4.0	BEUMER Group GmbH & Co. KG	Logistics	251-5000
RetailApps for Retail 4.0	Bizerba SE & Co. KG	Manufacturing & Production	251-5000
Smart advanced process control and operator assistance with PivotWare by	Desoutter	Engineering & Electronics	251-5000
Kurtz Central Management 4.0	Kurtz GmbH	ELectronics	251-5000
Industrial Cloud Communication	netIOT	Software	251-5000
Software tools for multi-adaptive CPPSs	SmartF-IT	Software	251-5000
Smart IPN	Bosch Group	Engineering & Electronics	251-5000
Virtual Commissioning	Viastore	Logistics	251-5000
Digital Factory of the Cooperative State University Mosbach (DHBW)	Baden-Württemberg Cooperative	Training, Research & Development	1-250
Agent-Based Networks for Cyber–Physical Production Systems (CPPS),	TU München	Training, Research & Development	1-250
Autonomous guided vehicle - "Flunder"	BÄR Automation GmbH	Robotics	1-250
Prognostic Technology for Industry: Data-based Information about the Future	Cassantec	Software	1-250
EIM-Ways	EIMcomponents GmbH	Software	1-250
Big Data in battery production	Electromobility laboratory – eLAB	Training, Research & Development	1-250
Energy Management using the MESSDAS® Energy Management System	Hochhuth GmbH	B2B company	1-250
Augmented Automation	Essert GmbH	Automation & Manufacturing	1-250
Industry 4.0 from A to Z	EVO Informationssysteme GmbH	Software	1-250
Flexible assembly in vehicle production	BÄR Automation GmbH	Automation & Manufacturing	1-250
Printing according to Industry 4.0	Hofmann GmbH & Co. KG	Printing	1-250
Industry 4.0 based complete solution toolkit	VIRTENIO	Engineering & Electronics	1-250
Industry 4.0 Training Area	Institute of Production Systems (IPS	Training, Research & Development	1-250
Integrated humanitarian Logistics	Catkin GmbH	Logistics	1-250
IoT Platform	M&M Software GmbH	Software	1-250
Smart camera in the Industry 4.0 environment	MATRIX VISION GmbH	Engineering & Electronics	1-250
On-time shipping control using the digital pull system	Rota Yokogawa GmbH & Co. KG	Manufacturing & Production	1-250
MANUSERV	RIF Institute for Research and Trans	Training, Research & Development	1-250
Value stream orientated production control	WZL at RWTH Aachen	Training, Research & Development	1-250

Type of Industry Segment	Number	Percentage
Telecommunication	2	4%
Engineering & Electronics	10	21%
Manufacturing & Production	7	15%
Energy	1	2%
Logistics(logistics + Intralogistics)	4	9%
Automation & Manufacturing	9	19%
Software	6	13%
Training, Research & Development	6	13%
Robotics	2	4%
B2B company	1	2%
Print Industry	1	2%

Domain Of Customization	Number of Projects	Percentage
Hardware	6	12%
Software	20	41%
Integration	22	45%
Training	1	2%

Technological Tools Used	Number of Projects	Percentage
Communication Network	16	33%
IOT	27	55%
CPPS	8	16%
Cyber Security	6	12%
3D Printing	3	6%
Smart Systems	35	71%
BlockChain	0	0%
Big Data Analytics	29	59%
Major I4.0 Tools	27	55%
Simulation	4	8%
Wearables	2	4%

Non Tecnical Tools	Number of Projects	Percentage
Strategic & Business Tools	5	10%
Educational Tools	8	16%

Smart Systems	Number of Projects	Percentage
Smart Grid	1	2%
Smart Sensor	13	27%
smart Technology	28	57%
Collaborative Technology	5	10%

Communication Network	Number of Projects	Percentage
Wireless Network	4	8%
Cloud	12	8%

Major I4.0 Tools	Numer of Projects	Percentage
Artificial Intelligence	6	12%
Virtual/Augmented Reality	7	14%
Robotics	9	18%
Automation	23	47%

Size of Company	Number of Projects	Percentage
1-250	19	39%
251-5000	10	20%
5001-15000	8	16%
15000+	12	24%

Targets	Number of Projects	Percentage
Operational Target	45	92%
Lower Cost	14	29%
Environment	12	24%
Adaptability	21	43%
Transparency	10	20%
Communication	23	47%
Security of Work	8	16%
Training, breakthrough in research	12	24%
Workers Safety and Skill Improvement	20	41%

Operational	Number of Projects	Percentage
Productivity	16	33%
Efficiency	35	71%
Higher Quality	13	27%
Optimisation	25	51%
Time Saving	26	53%
Real Time	30	61%
Reliability & Maintenance Ef	20	41%

Environmental Control	Number of Projects	Percentage
Smart Energy Consumption	9	18%
Sustainability	4	8%

Communication	Number of Project:	Percentage
Data Sharing	18	37%
Decision Making	9	37%

Adaptability	Number of Projects	Percentage
Flexibility	20	41%
Customization	11	22%

Appendix 2

List of Projects in France

Title Of the project	Company Name	Type of Industry Segment	Size of Industry
PLANT OF THE FUTURE OF FRUITS AND VEGETABLES	Agri-Food Technology Resource Center	Manufacturing & Production	20-49
DIGITIZATION AND ROBOTIZATION	ALLIANSYS	Manufacturing & Production	50-250
DRIVEYOURTOOLS - ENTERPRISE ASSETS INTELLIGENCE	BAW Solutions DriveYourTOols	ICT	0-19
ROBOTIC PRECISION MACHINING OF COMPETITION	Boust SN	Manufacturing & Production	20-49
ROBOTIZE TO ENTER THE BIG SERIES	CFT Industry	Automation & Manufacturing	0-19
ROBOTIC WELDING TO SLASH CHAMPAGNE	Groupe Chalvignac	Manufacturing & Production	50-250
ROBOTALIZE TO RELOCATE	Davoise	Manufacturing & Production	50-250
ONGOING INNOVATION AND TRAINING	E.C.R.I	Training, Research & Development	0-19
ROBOTS HELP THE JOB	Georges Pernoud	Automation & Manufacturing	20-49
ROBOTIZE TO AFFORD A FUTURE	GCB France	Automation & Manufacturing	50-250
ROBOTIC INDUSTRIAL MAINTENANCE	SMRI	Automation & Manufacturing	250-499
A DUO OF ROBOTS FOR THE CYLINDERS	SERTA Hydraulic Global Solutions	Automation & Manufacturing	250-499
ELECTRONIC LABELS	SECO Tools	ICT	250-499
REORGANIZATION OF THE FLOWS AND COMMERCIAL MODERNIZATION BY THE VR	AG Dynamics	ICT	250-499
AUTOMATIC PALLETIZATION OF TONER CARTRIDGES	TOSHIBA	Automation & Manufacturing	50-250
RENOWNED PARTNERSHIPS FOR MODERNIZED FACTORY	STSM	Automation & Manufacturing	50-250
A STRATEGIC ALLIANCE TO SERVE THE AVIATION MARKET	SOCIETE VENDEENNE DE CHAUDRONNERIE	Automation & Manufacturing	50-250
AUTOMATED ASSEMBLY, INSURED EXPORT	SERIPLAST	Automation & Manufacturing	50-250
NON STOP MACHINING	SCHRUB	Automation & Manufacturing	50-250
ALLIANCE STRATEGIES TO WIN BACK THE MARKET	Pubert	Manufacturing & Production	50-250
MES SOFTWARE FOR A CHAMPION MADE IN FRANCE	PLASTICS AND WEAVING OF LUNERAY	ICT	50-250
A PROJECT THAT PACKS THE ENVIRONMENT	MEDA MANUFACTURING	Pharmaceuticals	50-250
IT'S ABOUT PERMANENT INNOVATION	MECALECTRO	Manufacturing & Production	50-250
THE ROBOT SOUNDS THE DEATH KNELL FOR PAINFUL TASKS	Mauser France	Automation & Manufacturing	50-250
FACTORY OF THE FUTURE FOR ELECTRONICS MADE IN FRANCE	BMS Circuits	Automation & Manufacturing	50-250
A ROBOT TO SEAL A FRENCH SUBCONTRACTING	DEFAMETAL	Automation & Manufacturing	20-49
IMPROVE THE QUALITY SYSTEM AND AUTOMATE ADMINISTRATIVE TASKS	G. Chambert	Automation & Manufacturing	20-49
ROBOTIZE TO INNOVATE EVEN MORE	JOUSSELIN-PREFABRICATION	Automation & Manufacturing	20-49
A MACHINING MACHINE, 60% NEW PROJECTS	Monin Mecanique	Manufacturing & Production	20-49
WHEN TECHNOLOGICAL INNOVATION CREATES 300 JOBS	Techniwood	Manufacturing & Production	0-19
A WORLD FIRST AGAINST POLLUTION	Tallano Technologie	Automation & Manufacturing	0-19
NORMANDY ADDITIVE MANUFACTURING EXCELLENCE PROJECT (PEFA)	LU-OUT	Manufacturing & Production	0-19

Type of Industry Segment	Number	Percentage
Manufactruing & Production	10	31%
Automation & Manufactruing	16	50%
ICT	4	13%
Training, Research & Development	1	3%
Pharmaceuticals	1	3%

Domain Of Customization	Number of Projects	Percentage
Hardware	17	53%
Software	6	19%
Integration	9	28%

Technological Tools Used	Number of Projects	Percentage
Communication Network	2	6%
IOT	1	3%
CPPS	0	0%
Cyber Security	1	3%
3D Printing	1	3%
Smart Systems	11	34%
BlockChain	0	0%
Big Data Analytics	4	13%
Major I4.0 Tools	23	72%
Simulation	5	16%
Wearables	0	0%

Non Tecnical Tools	Number of Projects	Percentage
Strategic & Business Tools	5	16%
Educational Tools	2	6%

Smart Systems	Number of Projects	Percentage
Smart Grid	0	0%
Smart Sensor	1	3%
smart Technology	4	13%
Collaborative Technology	7	22%

Communication Network	Number of Projects	Percentage
Wireless Network	1	3%
Cloud	1	3%

Major I4.0 Tools	Numer of Projec	Percentage
Artificial Intelligence	1	3%
Virtual/Augmented Reality	2	6%
Robotics	17	53%
Automation	10	31%

Size of Company	Number of Projects	Percentage
0-19	6	19%
20-49	7	22%
50-250	15	47%
250-499	4	13%

Targets	Number of Projects	Percentage
Operational Target	32	100%
Lower Cost	12	38%
Environment	7	22%
Adaptability	12	38%
Transparency	0	0%
Communication	1	3%
Security of Work	3	9%
Training, breakthrough in research	3	9%
Workers Safety and Skill Improvement	21	66%

Operational	Number of Projects	Percentage
Productivity	24	75%
Efficiency	19	59%
Higher Quality	14	44%
Optimisation	10	31%
Time Saving	16	50%
Real Time	5	16%
Reliability & Maintenance	3	9%

Environmental Control	Number of Projects	Percentage
Smart Energy Consumption	5	16%
Sustainability	4	13%

Communication	Number of Proje	Percentage
Data Sharing	1	3%
Decision Making	1	3%

Adaptability	Number of Projects	Percentage
Flexibility	11	30%
Customization	3	8%

Appendix 3

List of Projects in Spain

Title Of the project	Company Name	Type of Industry	Size of Industry
GEOMOVE	EUROCAT	Training, Research & Development	251-5000
MAIC	EUROCAT	Training, Research & Development	251-5000
ROBOTRACK	EUROCAT	Training, Research & Development	251-5000
UNIKO	EUROCAT	Training, Research & Development	251-5000
AUTENTICLOUD	EUROCAT	Training, Research & Development	251-5000
BELIEVE	EUROCAT	Training, Research & Development	251-5000
OTBio Identity	EUROCAT	Training, Research & Development	251-5000
Kairós	EUROCAT	Training, Research & Development	251-5000
PREMIA	EUROCAT	Training, Research & Development	251-5000
PECT	EUROCAT	Training, Research & Development	251-5000
COT Project	Interactive Technologies Group,Universitat Pompeu Fabra.	Training, Research & Development	1-250
Metis: Meeting teachers co-design needs by means of Integrated Learning Environments	Interactive Technologies Group,Universitat Pompeu Fabra.	Training, Research & Development	1-250
IMPART. Intelligent Management Platform for Advanced Real-Time media processes	Interactive Technologies Group,Universitat Pompeu Fabra.	Training, Research & Development	1-250
Automatic Sign Language Avatar for video News	GTI Graphics Group	Software	1-250
FireDMMI - Fire Detection and Monitoring using Multispectral Imaging	CVC University Autonoma Barcelona	ICT	1-250
ACDC: Perception Automated and Cooperative Driving in the City	CVC University Autonoma Barcelona	ICT	1-250
ORANGE SMART CITY	I2CAT,The Internet Research Center	ICT	1-250
DEVELOPMENT OF A LEATHER CLASSIFICATION SYSTEM BY MEANS OF ARTIFICIAL VISION	DataScince Lab, UoBarcelona	Training, Research & Development	1-250
Artificial Intelligence for Finance	IIIA,Spanish Council for Scientific Research ,funding KLB Compan	Training, Research & Development	1-250
Logistar	IIIA,Spanish Council for Scientific Research , funding Horizon2020	Logistics	1-250
5GCroCo - 5G Cross-border Control	CTTC, Funding European	ICT	1-250
SEMIoTICS - Smart end-to-end Massive IoT Interoperability, Connectivity and Security	CTTC, Funding European	ICT	1-250
BEinCPPS project	Innovalia Association, Politecnico Di Milano	ICT	251-5000
Psymbiosys	Innovalia Association	Training, Research & Development	251-5000
Collaborative Analytics Platform	Innovalia Association	Software	251-5000
Predictive Inference	Techvolution	ICT	1-250
Intelligent e-commerce	Techvolution	ICT	1-250
cybersecurity solutions for Industry 4.0	Keynetic	ICT	1-250
AceroDocs	AceroDocs	ICT	1-250
Fagor Volteo Molde	Solid Virtual, Fagor Ederlan Group	Software	251-5000
AR Apps Mercedes	Solid Virtual, Mercedes-Benz	Software	251-5000
Implementation of VR based training for assembly	Solid Virtual, CAF	Software	251-5000
Cyber Deception Platform:	Counter Craft	ICT	1-250
Mesbook	Masbook	ICT	1-250
EnerCiudad 2020	EUROCAT	ICT	251-5000
Coolfox trackers	Stockare	ICT	1-250
WORKERS SAFETY ANALYTICS	WearHealth	ICT	1-250

Type of Industry Segment	Number	Percentage
ICT	15	41%
Software	5	14%
Training, Research & Development	16	43%
Logistics	1	3%

Domain Of Customization	Number of Projects	Percentage
Hardware	3	8%
Software	23	62%
Integration	11	30%

Technological Tools Used	Number of Projects	Percentage
Communication Network	11	30%
IOT	9	24%
CPPS	1	3%
Cyber Security	9	24%
3D Printing	2	5%
Smart Systems	10	27%
BlockChain	1	3%
Big Data Analytics	14	38%
Major I4.0 Tools	18	49%
Simulation	1	3%
Wearables	1	3%
Non Tecnical Tools	**Number of Projects**	**Percentage**
Strategic & Business Tools	4	11%
Educational Tools	7	19%

Smart Systems	Number of Projects	Percentage
Smart Grid	1	3%
Smart Sensor	6	16%
smart Technology	5	14%
Collaborative Technology	0	0%

Communication Network	Number of Projects	Percentage
Wireless Network	3	8%
Cloud	8	22%

Major I4.0 Tools	Numer of Projects	Percentage
Artificial Intelligenc	10	27%
Virtual/Augmentec	7	19%
Robotics	3	8%
Automation	2	5%

Size of Company	Number of Projects	Percentage
1-250	20	54%
251-5000	17	46%

Targets	Number of Projects	Percentage
Operational Target	27	73%
Lower Cost	6	16%
Environment	4	11%
Adaptability	7	19%
Transparency	4	11%
Communication	17	46%
Security of Work	9	24%
Training, breakthrough in research	6	16%
Workers Safety and Skill Improvement	10	27%

Operational	Number of Projects	Percentage
Productivity	7	19%
Efficiency	19	51%
Higher Quality	12	32%
Optimisation	12	32%
Time Saving	5	14%
Real Time	15	41%
Reliability & Maintenance	3	8%

Environmental Control	Number of Projects	Percentage
Smart Energy Consumption	4	11%
Sustainability	3	8%

Communication	Number of Projects	Percentage
Data Sharing	15	41%
Decision Making	10	27%

Adaptability	Number of Projects	Percentage
Flexibility	7	19%
Customization	2	5%

Appendix 4

List of Projects in Italy

Title Of the project	Company Name	Type of Industry Project	Size of Industry
Enel IoT platform	ENEL	Energy	15000+
Energy Monitoring and Management system using ENEL IOT PLANTFORM for a production site related to	ENEL	Energy	15000+
Educational Courses and Training Material	Avio Aero	Aerospace	251-5000
Data lake	Avio Aero	Aerospace	251-5000
Introduction of digital twin	Avio Aero	Aerospace	251-5000
Digitalization of Industrial process	Avio Aero	Aerospace	251-5000
reduction of unplanned machine downtime and intervention costs for maintenance and spare parts warehouse for a compressor making industry	Hewlett Packard	ICT	15000+
Implementation of 3D printing for product innovvation	Philip Morris	Manufacturing & Production	15000+
Implementing Automated Guided vehicles	Philip Morris	Manufacturing & Production	15000+
Radio frequency identification	Philip Morris	Manufacturing & Production	15000+
Visual control and Maintenance	Philip Morris	Manufacturing & Production	15000+
Setting management	Philip Morris	Manufacturing & Production	15000+
Self learning project	Philip Morris	Manufacturing & Production	15000+
Collaborative automation systems for materials handling	Whirlpool	Manufacturing & Production	15000+
New technology for testing	Whirlpool	Manufacturing & Production	15000+
Data visualisation and alalytics	Whirlpool	Manufacturing & Production	15000+
Connected Appliances	Whirlpool	Manufacturing & Production	15000+
HoloLens	Iveco, Microsoft	Automotive	15000+
RFID technologies for warehouse logistics management	IVECO	Automotive	15000+
ENG4AUTO	ENG	ICT	5001-15000
DIVE (Digital Virtualization Experience)	ENG in Collaboration with Comau	ICT	5001-15000
HUMANufacturing	Comau	Robotics	5001-15000
New robotics and industrial automation research laboratory	University of Bologna and the Institute of Intelligent Industrial Systems and Technologies for Advanced Manufacturing (STIIMA)	Training, Research & Development	1-250
Digital Innovation Hub Sardegnia	Regione Sardegna, is promoted by the Universities of Cagliari and Sassari, in collaboration with UnionCamere and Confindustria Sardegna, Confindustria digitale and Sardegna Ricerche	Training, Research & Development	251-5000
GOAL-BASED OPEN ENDED AUTONOMOUS LEARNING ROBOTS	Institute of Cognitive Sciences and Technologies of the Italian National Research Council	Training, Research & Development	1-250
AIDCoin project	Charity Stars	ICT	1-250
Friendz coins	Friendz SA	ICT	1-250
Facility Management	Microsoft Italy, Leonardo Global Solutions	ICT	15000+
Connected Coffee Machine	Cimbali Group	Manufacturing & Production	251-5000
Assistance to residence guests for elderly, IBM project	Sole Cooperative	Social Welfare	1-250
Fluid-o-Tech smart factory	Fluid-o-Tech	Manufacturing & Production	251-5000
Redesign of Plant	Celli Group	Food & Beverages	251-5000
Automatic systems for assemblies and tests	Masmec SpA	Automation & Manufacturing	1-250
AN.DY Advancing Anticipatory Behaviors in Dyadic Human-Robot Collaboration	Instituto Italiano Di Technologia	Training, Research & Development	251-5000
SECURE - Marie Sklodowska-Curie Action	IIT with funding from European Commission	Training, Research & Development	251-5000
Soma project	IIT & University of Pisa, Italy, IST Austria, Technische Universitat Berlin, Ocado Group , Ocado Group with funding from the European Union's Horizon 2020	Training, Research & Development	251-5000
Humanoids and Human Centered Mechatronics: WALK-MAN Humanoid, COMAN Humanoid	IIT Central Research Lab Genova	Training, Research & Development	251-5000
Smart PaintShop	Geico taikisha	Automation & Manufacturing	251-5000
Sherlock IoT for bicycles	Sherlock	ICT	1-250
Manutelligence	A consortium with Coordiantor from Dassault Systems Italy	Training, Research & Development	251-5000
Digital transformation to the cloud	Lavazza through Storm Reply	FOod & Beverages	251-5000
smart waste management	Gruppo Hera	Multiutility	5001-15000
BEinCPPS project	Politecnico DI Milano	Training, Research & Development	251-5000

Type of Industry Segment	Number	Percentage
Automation & Manufacturing	2	5%
Aerospace	4	9%
Automotive	2	5%
Energy	2	5%
Food & Beverages	2	5%
ICT	5	12%
IT Servitization	2	5%
Training, Research & Development	9	21%
Manufacturing & Production	12	28%
Multiutility	1	2%
Robotics	1	2%
Social welfare	1	2%

Domain Of Customization	Number of Projects	Percentage
Hardware	15	35%
Software	10	23%
Integration	18	42%

Technological Tools Used	Number of Projects	Percentage
Communication Network	10	23%
IOT	21	49%
CPPS	4	9%
Cyber Security	7	16%
3D Printing	4	9%
Smart Systems	15	35%
BlockChain	2	5%
Big Data Analytics	15	35%
Major I4.0 Tools	25	58%
Simulation	3	7%
Wearables	4	9%

Non Tecnical Tools	Number of Projects	Percentage
Strategic & Business Tools	3	7%
Educational Tools	6	14%

Smart Systems	Number of Proje	Percentage
Smart Grid	0	0%
Smart Sensor	4	9%
smart Technology	13	30%
Collaborative Technology	4	9%

Communication Network	Numb	Percentage
Wireless Network	2	5%
Cloud	8	19%

Major I4.0 Tools	Numer of Proj	Percentage
Artificial Intelligence	10	23%
Virtual/Augmented Reality	7	16%
Robotics	11	26%
Automation	14	33%

Size of Company	Number of Projects	Percentage
1-250	7	16%
251-5000	16	37%
5001-15000	4	9%
15000+	16	37%

Targets	Number of Projects	Percentage
Operational Target	40	93%
Lower Cost	8	19%
Environment	8	19%
Adaptability	22	51%
Transparency	8	19%
Communication	27	63%
Security of Work	18	42%
Training, breakthrough in research	8	19%
Workers Safety and Skill Improvement	17	40%

Operational	Number of Proje	Percentage
Productivity	9	21%
Efficiency	33	77%
Higher Quality	16	37%
Optimisation	13	30%
Time Saving	23	53%
Real Time	20	47%
Reliability & Mainte	20	47%

Environmental Control	Numb	Percentage
Smart Energy Consumption	8	19%
Sustainability	2	5%

Communication	Number of Pro	Percentage
Data Sharing	19	44%
Decision Making	18	42%

Adaptability	Number of Projec	Percentage
Flexibility	22	51%
Customization	7	16%

Appendix 5

List of Projects in United Kingdom

Title Of the project	Company Name	Type of Industry	Size of Industry
A Demonstration of Design Optimisation and Hybrid Additive Manufacturing of a Nozzle for the Food Industry	Matsuura Machinery LtD	Manufacturing & Production	251-5000
Advanced automatic inspection for printed circuit board assemblies	Nikon	Manufacturing & Production	15000+
Advanced Manufacturing for Complex Avionics	GE	Manufacturing & Production	15000+
Cordless Automated Smart Drill Improves Aero-Structure Production	MTC	Manufacturing & Production	251-5000
Embedded Sensors for intelligent Composite Structure	National Composites Centre	Manufacturing & Production	251-5000
Revolution Very Light Rail (VLR)	WMG	Training, Research & Development	251-5000
3D Scanning Technology	Vortex Exhaust Technology Ltd	Automotive	1-250
CAVE System: Immersive Visualization as a decision platform for collaborative construction project	Gleeds	Consulting	1-250
Operational Efficiency Delf	Delf	Product Supplier	1-250
Flexible Automation System	AFRC	Training, Research & Development	1-250
Embedded Sensing Feasibility Study	MTC	Training, Research & Development	251-5000
PragmatIC work with CPI to progress flexible integrated circuit technology	PragmatIC	Engineering & Electronics	1-250
KeyTalk IoT Secured Sensors	GeDaP	Manufacturing & Production	1-250
CITYVERVE	IOTUK Industries	City Administration	251-5000
Valkyrie Project	Valkyrie	Manufacturing & Production	1-250
Wireless Sensor System	4D Products	Sensor Technology	1-250

Type of Industry Segment	Number	Percentage
Sensor Technology	1	6%
Engineering & Electronics	1	6%
Manufacturing & Production	7	44%
Product Supplier	1	6%
Consulting	2	13%
Automotive	1	6%
Training, Research & Development	3	19%

Domain Of Customization	Number of Projects	Percentage
Hardware	2	13%
Software	3	19%
Integration	11	69%

Technological Tools Used	Number of Projects	Percentage
Communication Network	5	31%
IOT	2	13%
CPPS	0	0%
Cyber Security	2	13%
3D Printing	0	0%
Smart Systems	13	81%
BlockChain	0	0%
Big Data Analytics	4	25%
Major I4.0 Tools	10	63%
Simulation	2	13%
Wearables	1	6%

Non Tecnical Tools	Number of Projects	Percentage
Strategic & Business Tools	2	13%
Educational Tools	1	6%

Smart Systems	Number of Projects	Percentage
Smart Grid	0	0%
Smart Sensor	7	44%
smart Technology	7	44%
Collaborative Technology	1	6%

Communication Network	Number of Projects	Percentage
Wireless Network	5	31%
Cloud	1	6%

Major I4.0 Tools	Numer of Projec	Percentage
Artificial Intelligence	1	6%
Virtual/Augmented Reality	5	31%
Robotics	2	13%
Automation	6	38%

Size of Company	Number of Projects	Percentage
1-250	7	47%
251-5000	6	40%
5001-15000	0	0%
15000+	2	13%

Targets	Number of Projects	Percentage
Operational Target	16	100%
Lower Cost	6	38%
Environment	2	13%
Adaptability	7	44%
Transparency	2	13%
Communication	5	31%
Security of Work	2	13%
Training, breakthrough in research	2	13%
Workers Safety and Skill Improvement	8	50%

Operational	Number of Projects	Percentage
Productivity	3	19%
Efficiency	11	69%
Higher Quality	4	25%
Optimisation	3	19%
Time Saving	8	50%
Real Time	4	25%
Reliability & Maintenance	3	19%

Environmental Control	Number of Projects	Percentage
Smart Energy Consumption	2	13%
Sustainability	1	6%

Communication	Number of Proje	Percentage
Data Sharing	5	31%
Decision Making	0	0%

Adaptability	Number of Projects	Percentage
Flexibility	7	44%
Customization	1	6%

Appendix 6

List of Projects in China

Title Of the project	Company Name	Type of Industry	Size of Industry
MACE AI project	XIAOMI	Telecommunication	5001-15000
Medical Imaging Artificial Intelligence Research Platform	YITU	AI Technology	251-5000
Dragonfly Eye	YITU	AI Technology	251-5000
Wireless AI	Huawei	Telecommunication	15000+
Predictive Maintenance & Digital Factory Solution	XCMG	Manufacturing & Productic	5001-15000
Automated Factory	INESA	ICT	5001-15000
smart manhole cover system	TelChina	Telecommunication	251-5000
ET Industrial Brain	Alibaba Cloud	Cloud Services	251-5000
Autonomous Car	Didi Chuxing	Transportation	5001-15000
Didi Smart Transportation Brain	Didi Chuxing	Transportation	5001-15001
Real-time System Modeling and Energy Management for Safety-Critical Technology Research on CPS	RTES Lab- Northeastern Univer	Training, Research & Deve	1-250
Intelligent Visualization Display	FUJITSU	Software	15000+
Blockchain Platform	Loudi City Administration	City Administration	251-5000

Type of Industry Segment	Number	Percentage
Telecommunication	3	25%
AI	2	17%
Cloud Service	1	8%
Transportation	2	17%
Government Service	1	8%
ICT	1	8%
Software	1	8%
Training, Research & Development	1	8%
Manufacturing & Production	1	8%

Domain Of Customization	Number of Projects	Percentage
Hardware	0	0%
Software	5	38%
Integration	8	62%

Technological Tools Used	Number of Projects	Percentage
Communication Network	11	85%
IOT	13	100%
CPPS	1	8%
Cyber Security	3	23%
3D Printing	0	0%
Smart Systems	9	69%
BlockChain	1	8%
Big Data Analytics	11	85%
Major I4.0 Tools	11	85%
Simulation	4	31%
Wearables	0	0%

Non Tecnical Tools	Number of Projects	Percentage
Strategic & Business Tools	2	15%
Educational Tools	1	8%

Smart Systems	Number of Projects	Percentage
Smart Grid	0	0%
Smart Sensor	6	46%
smart Technology	8	62%
Collaborative Technolog	1	8%

Communication Network	Number of Projects	Percentage
Wireless Network	6	46%
Cloud	7	54%

Major I4.0 Tools	Numer of Projec	Percentage
Artificial Intelligence	9	69%
Virtual/Augmented Reality	2	15%
Robotics	3	23%
Automation	2	15%

Size of Company	Number of Projects	Percentage
1-250	1	8%
251-5000	5	42%
5001-15000	5	42%
15000+	1	8%

Targets	Number of Projects	Percentage
Operational Target	13	100%
Lower Cost	4	31%
Environment	7	54%
Adaptability	8	62%
Transparency	6	46%
Communication	12	92%
Security of Work	6	46%
Training, breakthrough in research	5	38%
Workers Safety and Skill Improvement	3	23%

Operational	Number of Projects	Percentage
Productivity	2	15%
Efficiency	10	77%
Higher Quality	2	15%
Optimisation	8	62%
Time Saving	10	77%
Real Time	12	92%
Reliability & Maintenance	7	54%

Environmental Control	Number of Projects	Percentage
Smart Energy Consumption	6	46%
Sustainability	1	8%

Communication	Number of Proje	Percentage
Data Sharing	11	85%
Decision Making	7	54%

Adaptability	Number of Projects	Percentage
Flexibility	8	62%
Customization	1	8%

Appendix 7

List of Projects in Japan

Title Of the project	Company Name	Type of Industry	Size of Industry
Smart Dies	Gifu Tada Seiki Co., Ltd	Training, Researc & Development	21-300
Further Strengthening the Business Model through the Adoption and Deployment of Overall Equipment Efficiency (YKK IOT	YKK Business	Manufacturing & Production	300+
Ultra Compact IOT Modules	Paltek Co	Engineering & Electronics	21-300
Increase Customer Value with Effective Use of Big Data	Mazda Motor Corporation Production Engineering Division	Automotive	300+
Electronic Guidance System-Production innovation evolving with ma	SANYO DENKI	Manufacturing & Production	300+
Cloud aggregation of a design development environment with a high-	FUJITSU	Software	300+
Intuitive and easy virtual verification by stereoscopic viewing	FUJITSU	Software	300+
Advanced development of equipment with virtual verification environ	FUJITSU	Software	300+
IoT Cloud Data Services	Mitsubishi Heay Industries Machine Tool Co	Manufacturing & Production	300+
Muratec Smart Sapport (MSS) IoT for Texttile Machine	MURATA Machinery	Manufacturing & Production	300+
To utilize data by installing the factory network	JTEKT	Automotive	300+
Operation monitoring and reporting system using IoT and AI	iSmart Technologies- Mazak	Automation & Manufacturing	01 -20
Smart-Manufacturing Supporting Team	Softopia Japan	Training, Researc & Development	21-300
Improvement of operation efficiency by human-robot collaboration	Hitachi Ltd	Manufacturing & Production	300+
The frontier company applying robot at rice ball and boxed lunch pro	Musashino Co. Ltd	Food & Bevereges	300+
Electronic Guidance System-Production innovation evolving with	Sanyo Denki Co Ltd	Manufacturing & Production	300+
Remote Visualization of Operational Data Of An Automatic Inspectic	Hirotec Corporation	Automotive	300+
Building a next generation monozukuri environment (cooperation bet	FUJITSU Limited	Software	300+
Smart-Manufacturing Supporting Team	The Kitakyushu Chamber of Commerce and Industry	Training, Researc & Development	21-300
Sophisticating Manufacturing Through IoT	NEC	ICT	300+
BUDDY ~ Connect information and objects to respond to various nee	TAIEI Co Ltd	Engineering & Electronics	21-300
Plant factory business approach by utilizing IoT	FUJITSU	Software	300+

Type of Industry Segment	Number	Percentage
Automotive	3	14%
Engineering & Electronics	2	9%
Manufacturing & Production	6	27%
IT Servitization	1	5%
Food & Beverages	1	5%
Automation & Manufacturing	1	5%
Software	5	23%
Training, Research & Development	3	14%

Domain Of Customization	Number of Projects	Percentage
Hardware	3	14%
Software	9	41%
Integration	8	36%
Training	2	9%

Technological Tools Used	Number of Projects	Percentage
Communication Network	15	68%
IOT	17	77%
CPPS	0	0%
Cyber Security	0	0%
3D Printing	0	0%
Smart Systems	14	64%
BlockChain	0	0%
Big Data Analytics	17	77%
Major I4.0 Tools	9	41%
Simulation	3	14%
Wearables	2	9%

Non Tecnical Tools	Number of Projects	Percentage
Strategic & Business Tools	2	9%
Educational Tools	2	9%

Smart Systems	Number of Projects	Percentage
Smart Grid	0	0%
Smart Sensor	12	55%
smart Technology	8	36%
Collaborative Technology	2	9%

Communication Network	Number of Projects	Percentage
Wireless Network	9	41%
Cloud	7	32%

Major I4.0 Tools	Numer of Projec	Percentage
Artificial Intelligence	1	5%
Virtual/Augmented Reality	1	5%
Robotics	4	18%
Automation	6	27%

Size of Company	Number of Projects	Percentage
01-20	1	5%
21-300	5	23%
300+	16	73%

Targets	Number of Projects	Percentage
Operational Target	20	91%
Lower Cost	11	50%
Environment	3	14%
Adaptability	9	41%
Transparency	3	14%
Communication	17	77%
Security of Work	2	9%
Training, breakthrough in research	2	9%
Workers Safety and Skill Improvement	18	82%

Operational	Number of Projects	Percentage
Productivity	18	82%
Efficiency	13	59%
Higher Quality	10	45%
Optimisation	19	86%
Time Saving	16	73%
Real Time	10	45%
Reliability & Maintenance Effort	10	45%

Environmental Control	Number of Projects	Percentage
Smart Energy Consumption	3	14%
Sustainability	1	5%

Communication	Number of Proje	Percentage
Data Sharing	17	77%
Decision Making	4	18%

Adaptability	Number of Projects	Percentage
Flexibility	9	41%
Customization	1	5%

Appendix 8

List of Projects in the United States of America

Title Of the project	Company Name	Type of Industry Project	Size of Industry
Digitalizing F35 Production	Lockheed Martin	Aerospace	15000+
VTEM Motion Terminal	FESTO	Automation & Manufacturing	15000+
Project IRIS	RSA Lab	Training, Research& Development	251-5000
Project SIF	SIF Foundation	Social Welfare	251-5000
Plantweb™ digital ecosystem	Emerson Electric Co.	Energy	15000+
Icyphy	UC Berkelay	Training, Research& Development	251-5000
Mixed Reality	Magic Leap	ICT	251-5000
Tesla's Autopilot	Tesla Motors	Automotive	15000+
AI Data Pipeline-Enterprise Manufacturing Analytics	Sight Machine	Maufacturing & Production	1-250
Accurate Predictive Maintenance System for World Leading Screw and Nut Manufacturer	Advantech	Automation & Manufacturing	5001-15000
OTTO INVENTORY MOVEMENT PLATFORM	OTTO Motors	Automation & Manufacturing	1-250
OTTO Fleet Manager	OTTO Motors	Automation & Manufacturing	1-250
Learning Robots	The Moonshot Factory	Training, Research& Development	251-5000
Glass Enterprise	The Moonshot Factory	Training, Research& Development	251-5000
Predictive Quality	Amazon	E-commerce	15000+
Stochastic Neural Networks	Microsoft	ICT	15000+
Predix Platform	GE	Multiutility	15000+

Type of Industry Segment	Number	Percentage
Aerospace	1	6%
Automation & Manufacturing	4	24%
Energy	1	6%
ICT	2	12%
Automotive	1	6%
Training, Research & Development	4	24%
E-commerce	1	6%
Manufacturing & Production	1	6%
Social Welfare	1	6%
Multiutility	1	6%

Domain Of Customization	Number of Projects	Percentage
Hardware	1	6%
Software	8	47%
Integration	8	47%

Technological Tools Used	Number of Projects	Percentage
Communication Network	11	65%
IOT	15	88%
CPPS	1	6%
Cyber Security	7	41%
3D Printing	0	0%
Smart Systems	7	41%
BlockChain	1	6%
Big Data Analytics	11	65%
Major I4.0 Tools	6	35%
Simulation	1	6%
Wearables	1	6%

Non Tecnical Tools	Number of Projects	Percentage
Strategic & Business Tools	0	0%
Educational Tools	2	12%

Smart Systems	Number of Prc	Percentage
Smart Grid	0	0%
Smart Sensor	7	41%
smart Technology	6	35%
Collaborative Technology	1	6%

Communication Network	Number of Projects	Percentage
Wireless Network	4	24%
Cloud	9	53%

Major I4.0 Tools	Numer of Pr	Percentage
Artificial Intelligence	5	29%
Virtual/Augmented Reality	1	6%
Robotics	2	12%
Automation	3	18%

Size of Company	Number of Projects	Percentage
1-250	3	18%
251-5000	6	35%
5001-15000	1	6%
15000+	7	41%

Targets	Number of Projects	Percentage
Operational Target	15	88%
Lower Cost	3	18%
Environment	2	12%
Adaptability	14	82%
Transparency	1	6%
Communication	13	76%
Security of Work	2	12%
Training, breakthrough in research	2	12%
Workers Safety and Skill Improvement	6	35%

Operational	Number of Prc	Percentage
Productivity	5	29%
Efficiency	13	76%
Higher Quality	5	29%
Optimisation	8	47%
Time Saving	10	59%
Real Time	15	88%
Reliability & Maintenance Effort	8	47%

Environmental Control	Number of Projects	Percentage
Smart Energy Consumption	1	6%
Sustainability	1	6%

Communication	Number of P	Percentage
Data Sharing	10	59%
Decision Making	7	41%

Adaptability	Number of Proj	Percentage
Flexibility	14	82%
Customization	0	0%