POLITECNICO DI TORINO

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Master’s degree in Automotive Engineering

INDUSTRY 4.0 AND T.E.A.M.: TOOL FOR SUSTAINABILITY IN ADDITIVE MANUFACTURING

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ABSTRACT

This paper will consider the aspects that the fourth industrial revolution will bring to the manufacturing environment. It is a recent topic able to renew/expand the idea of productive environment worldwide and strengthening the competition.

The result consists on a research conducted at the Politecnico di Torino, oriented to make the reader aware of the Industry 4.0, an innovative challenge that companies are facing. This first part is more theoretical and it tries to list and analyze the peculiar aspects of the fourth industrial revolution (it took the early months).

The second part contains the description of the internship the writer has completed in two months at the Ecole Nationale Supérieure d'Arts et Métiers in Paris. Applying the knowledge acquired on the I4.0 and taking the available opportunities, it was possible to adopt the new technologies inside a manufacturing environment.

With this paper, an article has been written about the tool developed in ENSAM that is presented at the PLM conference in Torino within the 1st and the 4th of the next July.

At the end of the work there is an annex containing a description of the experience had in ENSAM.

INTRODUCTION

Since the introduction of the computers and the internet, many steps forward have been done and the technology implementation in our everyday life is becoming bigger year by year.

Some examples may be found in the development of mobile phones, storing an incredible amount of personal data and offering apps that simplify the ordinary life. Moreover, another case of technology implementation in daily life is the domotics, a type of automation that allows people to control the electrical appliances easy defining timing or using mobile devices.

The same process is happening in the manufacturing environment. The advanced technology and the web communications with the new technology introduced are renewing the way in which a company can add value to its products. The aim of this paper is to analyze, trying to forecast, the implementation of the new technologies within the concept of the industrial environment.

This work is developed in two separated sections: the first has been carried out at Politecnico di Torino and consists on a theoretical analysis of the literature about I4.0 coming from analysts, consulting companies and government plans for this technology. More precisely, there is an initial historical introduction to the argument of industrial revolution (by considering the past three). A consideration is taken of the worldwide strategy the governments are undertaking for facing this challenge and improving the local companies. As a comparison, aside of the plans presented by the states more involved in the implementation of the revolution, the Italian plan is presented and compared.

After that, the nine keys that enable technologies, defined by the Boston Consulting Group, are listed one by one with a brief description.

In the following two chapters, IoT and CPS are analyzed deeply, in order to make the reader able to figure out how many technology devices should be integrated in a productive plant in order to implement efficiently the new technological horizon.

The second, and final, part of this paper concerns the work performed at the Ecole Nationale Supérieure d'Arts et Métiers in Paris, in which the candidate has had an internship focused on developing an innovative tool for manufacturing companies within the idea of industry 4.0. This project matches more key points of the Industry 4.0 concept in order to create a tool able to simplify and improve the adoption of the Additive Manufacturing, especially for producing prototypes in the idea gathering and concept generation phase.

Chapter 1. HISTORY

We are talking about the industries 4.0, obviously it is easy to understand the link with the word industry, but why 4.0?
In order to understand the meaning of this number we have to make a backward pass through the history, in fact this is the fourth industrial revolution. Each industrial revolution had a strong impact in our life, both every day and professional life, moreover these revolutions took place in different regions all around the world and different industrial sectors, showing the increasing of the global impact of the industrial processes.

During the first (in Great Britain, 1760), the steam had made the energy transformation easier and allowed the exploit of that energy available to a lot of industries, above all the cotton transformation plants.

The second industrial revolution brought us the first mass production car, the Ford Model T, in 1908. From my point of view, this extraordinary event shows the impact that these revolutions have on every day and professional life. Obviously not only the carmakers had opportunities from it, the medical science had Robert Koch and in Italy Galileo Ferraris shook up the electricity production.

The seventies had an enormous impact on the industrial field. In the middle of the Space Race and a couple of decades after the computer's invention, the Information Technology was incredibly appealing for the worldwide companies and for the two world-powers, USA and Russia.

Nowadays, the market requirements for a more strengthened link between customer, company and suppliers, the user interface between machine and operator and the continuous thinking about reducing the environmental impact of the industrial field. All that has brought to 2011 at Hannover, where Henning Kagermann, Wolf-Dieter Lukas and Wolfgang Whalster used for the first time the term "Industry 4.0", defining it as "Zukunftsprojekt": a project for the future!

Chapter 2. GLOBAL TREND TOWARD INDUSTRY 4.0

The International Monetary Fund's researches sustains that the requirements from the market to the manufacturing have been increased of 3.1% in 2016 and they are still increasing in 2017 of 3.4% within the end of the year. This behavior is influenced by the Brexit and the political uncertainties, especially in the European manufacturing productivity and market requirements.

The KPMG reports suggest that the future of the manufacturing sector is very complex to predict because of the big companies' continuous research new opportunities in the market. Moreover, obviously, the availability of new opportunities makes the competitiveness even more strength, thus the company growth assumes a central role.

Furthermore, the web and the communication is "tightening" the world, so the markets, as well as the businesses, are influenced not only from the continental markets but also from the other parts of the world. The distinction between "old" and "emerging" markets becomes important and the surveys from KPMG report important distinction in their strategies.[1]
On one hand, the Japanese interviewed companies declare to follow an aggressive approach. On the other hand, only the 11% of the US, as well as the 8% of the German, companies are inclined to employ the same strategy.

Still KPMG indicates two ways for a company to grow, 'Acquisition and Merge' and 'Organic investments' (such as R&D). As reported in the following two charts, the second one is the preferred and this propensity is explained by the consultant as more focus on customers (for both products and services).

[1] KPMG – www.kpmg.com

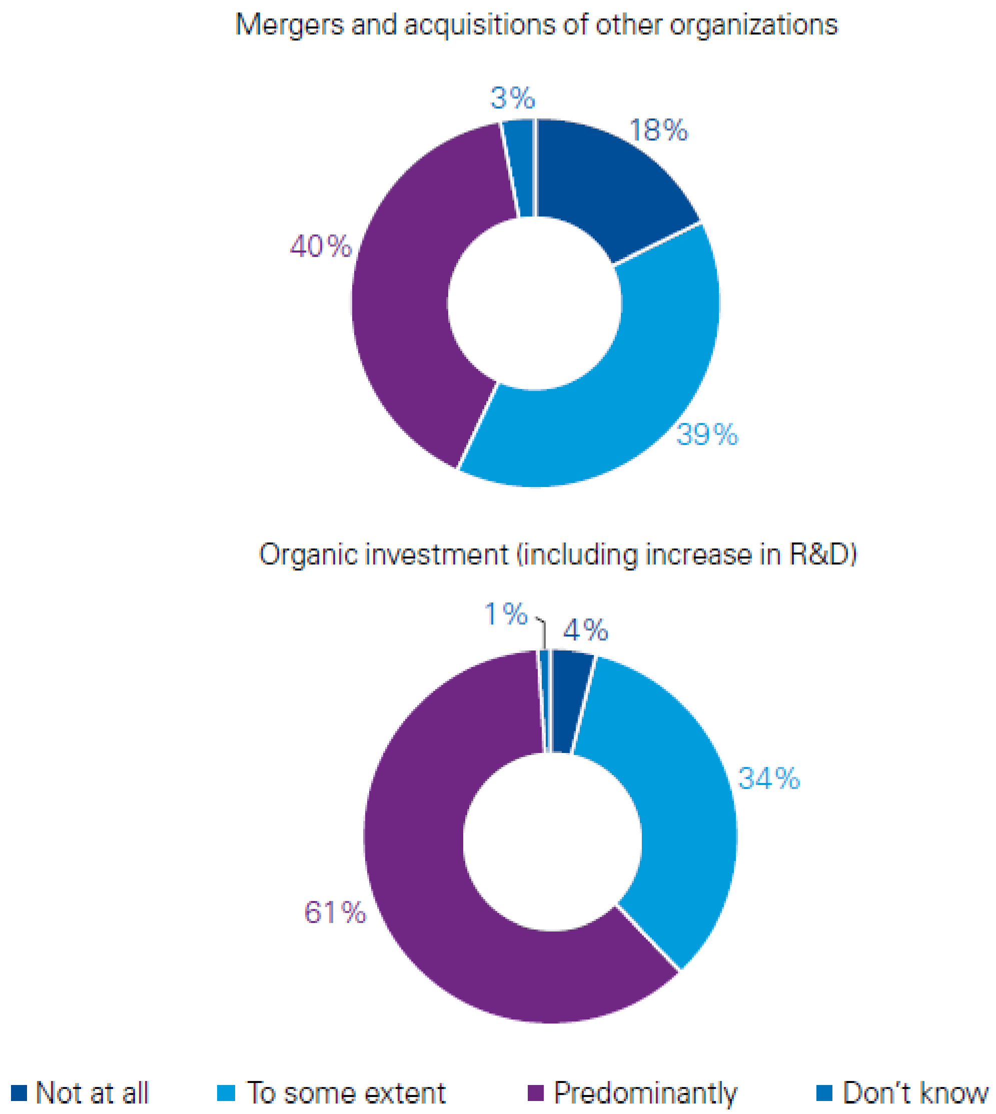

Figure 1. Growth tendency of companies - images from KPMG

Finally, PwC has recommended for the 2017 six actions, or more specifically, key points to be strengthened in order to increase the profits facing the challenges of the competitive markets.[2]

Leverage data and analytics in a new business model. The organization of the company must change radically. The first point to manage is the maintenance that cannot longer be reactive, but must become proactive.

Innovate pricing. The customers are become more demanding and aware of their influence with the decision to buy or not to buy a product or a service, thus the companies have to move their pricing model from pay-for-product to pay-for-performance.

Develop strategic partnerships.

[2] Explore innovation opportunities – PWC

Mine operational data. The backbone of the smart industries is the IoT, at today it is applied only on the machine to machine communication but companies should invest on this technology because it is expected to change the data management radically in the following five years.

Decide what intellectual property to share and what to develop. One for all, it is the improvement of the IT systems, to allow it to manage and communicate the amount of data with standardize protocols in order to integrate suppliers and make the production leaner.

Create strategies for talent development and retention.

Here there is a state by state analysis of how the governments are facing the Industry 4.0 challenge.

South Africa

South Africa has difficulties in fight in the manufacturing sector and for this reason the impact of Industry 4.0 is relatively low (as reported by Deloitte[3]). However, the emerging economy and the new technology adoption have become interesting for the local industrial leaders. The biggest challenge in the south Africa environment remains the accessibility and the connectivity, for implementing the Industry 4.0, particularly for the IoT. The wireless communication is the base of the fourth technological revolution and all the projects should be supported by public and private investments, but until today they are not so generous. Behind all these difficulties, South Africa has the advantage that the market is rising and the local economy is increasing, thus the potential of the region is quite high.
From the reports of Deloitte, the usage of smart technology in the country are:

Advanced analytics. There is a strong adoption in the automation and automotive sectors, the data is not fully exploited with respect to their potential (mainly because of the manufacturers do not know what kind of data they have[4]), the approach of the manufacturers is still reactive rather than predictive

Cloud computing. The cloud usage has increased a lot in the recent years and its adoption nowadays is stronger from the customer than the businesses, although this trend is expected to reverse soon.

Advance sensors. This is in the very first steps, today only the machine to machine communication has implemented this possibility (especially in the automotive industry and non-manufacturing sectors – logistic, retailing)

Advanced robotics. The adoption of this technology is even more a step backward than the advanced sensors, because it is still in an automated stage and not ready for the implementation, and besides, the costs make it even more unfeasible.

Additive manufacturing & 3D printing. This technology is in the first stages too, both in the low-level and mass productions, even if manufacturers are aware of its potential. Similarly, to the advanced robotics, the major constraint to the implementation of the rapid prototyping is the cost.

[3] Is Africa ready for digital transformation? – Deloitte.
[4] Ed.

China

China has "中国制造2025" -translated as "Made in China 2025". This program has been inspired directly by Germany's "Industrie 4.0" (that will be explained later) and the idea is applying tools of information technology to production, one of the milestones of the "Industry 4.0" program. This has been a decision from the Chinese government for lifting the country to a higher value-added economy.

The intensively growth of the Chinese economy in the lasts decades was driven by the manufacturing sector, especially by the surging investments, exploiting this characteristic, the government facilitated the migration of the foreign countries. In the last decade, from 2006 to 2016, as reported by the global briefing 'Industry 4.0: The Future Impact of the Fourth Industrial Revolution', the Chinese manufacturing turnover was expanding at a CAGR (Compound Annual Growth Rate) of 10%, the main contribution coming from the high-tech goods. However, this increasing trend has decelerated in the last year, in fact in 2016 the growing tendency has been of the 5%, limited if compared to the yearly 20% of a decade ago.[5]

Moreover, the rising wages in china, the maturing of the internal market and the difficulty in penetrating in the global economy have outlined the need of this change. The labor cost is no more an advantage, since in the past decade was increasing of the 10% yearly and today it is more or less twice as expensive as in other low-cost countries. As a result, the need of a new way for the growing of the economy is essential. Especially for the medium sized companies that encounter even more difficulties in engage the mass production, thus they should focus their efforts to the products' customization.

The key aspects of China 2025 are the application of innovation-driven principle, the target of upgrading the Chinese industry (in efficiency and integration, even by rising the domestic components and material, 40% - by 2020 – and 70% - by 2025), the government will provide the overall framework (utilizing financial and fiscal tools, as well as manufacturing innovation centers) and upgrade the industry writ.

India

India has adopted initiatives as Green Corridors and "Make in India" for its emerging economy, inspired by the concept of industry 4.0. The aim is to increase the manufacturing output to 25% of Gross Domestic Product by 2025 (starting from the current 16%). The effort will be put on the "Internet of Things", with the intention to capture un to 20% of the IoT global market within five years, according to the India Brand Equity Foundation previsions. The Automotive filed is the winning horse on which India government and companies have bet on, because of its growing market. For this reason, also the third industrial revolution was firstly implemented in Bajaj Auto with a huge investment in robots both collaborative and not. The competitive landscape is majorly with the Chinese market, in fact the plan is mainly oriented through that competition in the short terms. Anyway, in the long terms, the competitors in the target of this project are the occidental carmakers (GM, Ford, Volkswagen, Renault, FCA, BMW and Daimler) thanks to the significant increment of usage of domestic products.

The government has many expectations on the emerging carmakers (Delhi-Gurgaon-Faridabad in the north, Sanand-Halol and Mumbai-Pune-Nasik-Aurangabad in the west, Chennai-Bengaluru-Hosur in the south and Jamshedpur-Kolkata in the east,) because they already use 7,1% of India's GDP. Moreover, nowadays, India is the sixth largest market in automotive sector and it is expected to be the third within 2020 (obviously a strongpoint of this theory is the big amount of the population and the steep increasing of economy inside the state – for this reason this forecast regards India as both producer and consumer). The incentives for this industrial transformation regards, above all, the government with the Automotive Mission Plan 2016-26, that through economic and financial tools, as like as incentives, aims to increase the product exportation up to 35-40% of the overall output and generate more jobs. other important actions that have been taken

[5] Industry 4.0: The Future Impact of the Fourth Industrial Revolution – www.euromonitor.com

by the public administration are plans about electric and hybrid automotive market, the introduction of a new Transport Department comprising of experts in the automotive sector, emissions and alternative fuels.

Canada

The Canadian approach to the 4th industrial revolution has started with a feasibility analysis of the entrepreneurs and medium size business. The investment by the manufactures is significative, over the half have invested up to $100,000, the others achieved more than $1 million. However, as reported by the article 'Industry 4.0: The New Industrial Revolution', there is some inertia from the Canada entrepreneurs, in fact only the 3% have implemented the industry 4.0, while in the other regions of the world more companies are moving this step ahead.[6]
The four key points on which the Canadian revolution puts the efforts on are: focusing on customer needs (the motivation for buying a product), being strategic (pointing out the technologies to meet the first point, by evaluating the digital maturity inside the company), empowering the employees (fully involve all the actors inside the firm) and walking before running (start with small pilot projects for learning and only the implement it on larger scale). The expectations from the industry 4.0 of Canada are that companies will boost their productivity of 60%, reduce the operating costs by 50%, improve of 42% of the overall product quality and increase of 13% their capacity to innovate as a benefit.
The automotive business is expected to be one of the drivers of this revolution, both final products and parts suppling. This because, as a study of the 'Business Deployment Bank of Canada' outlines, the automotive parts is one of the most competitive sectors around the world, using very sophisticated technology, as robots, and manage a huge amount of data and information. As the co-president of AGS Automotive Systems and Tiercon Corp., Joe Loparco says "It's a whole other level of not only gathering data, but also being able to manage that data in a more holistic way." and he arguments, focusing on the automotive field "Automotive is a high-volume business. So, every time you can flush out an issue an hour earlier than before, you're saving big money. And if you can flush it out days earlier, you're saving really big money."[7]

South Korea

From the point of view of the research 'Industrie 4.0 in a Global Context' by 'Acatech STUDY', nowadays the south Korea is comparable to the Germany just after the fall of the Berlin wall, because of the past political tensions that have divided the nation in the past years.[8] The market growth is even bigger than what it could seem if it is thought that the population is approximately 51,5 million people, relatively small.
The South Korean internal economy is characterized by different types of industries, the big conglomerates (the chaebols) making business in the high tech and mechanical engineering sectors (for instance: Samsung, Hyundai, LG, SK Telecom and Posco) and around three million of small and medium-sized enterprises (SMEs), including the suppliers of the big chaebols. Due to this business composition inside the country, the South Korean Ministry of Science, ICT and Future Planning (MSIP) defined the real-time networking of objects via the Internet of Things (IoT).
The government plan is to converge the manufacturing and the IT system together, by four development fields:

[6] Industry 4.0: The New Industrial Revolution – BDG Study
[7] Industry 4.0: The New Industrial Revolution – BDG Study
[8] Industrie 4.0 in a Global Context – Acatech STUDY

Spread of smart manufacturing process (improving the smart factory, the software technologies and enhancing the production facilities)

Create representative new industry (commercializing and developing intelligent materials and investing on R&D)

Reform regional manufacturing industry (activation of startups and using the local strategic points to become smart industrial regions)

Foundation, construction by promoting & reorganizing new business (promoting and reorganizing business in the private sectors)

The forth industrial revolution is believed to have an important boost to the national industry with respect to the third, because of the high content in information technology and management of information due to the limited number of South Korean industries implementing big automation systems.
On one hand, the effort is performed from the Ministry of Trade, Industry and Economy (MOTIE) for allowing companies to build up a testbed, do researches and develop the smart factory system. In 2015, 26 million euro were spent by the MOTIE, at the same time the other ministry MSIP had secured a budget of 9,7 million euro to initiate the 'Connected Smart Factory (CSF)' project (consisting in producing, testing and certifying precision motors and using this project as demonstration inside the companies of the country).
At the same time, the Korean government, local government and the large conglomerates are cooperating for improving the regional business strength. The achievement of this target is pursued by sharing the technologies among the three cited actors, for example, Samsung Electronics is providing consulting service and proceeding knowledge transfer on the production design simulation and the establishment of smart factories at the Gyeong Buk Creative Economy Innovation Center.

Japan

Japan is the world's third largest economy after the US and China, even if its area is too much small if compared with the other two. Thank also to the large importation of food and raw materials, the exporting sector works with numerous global conglomerates. There are globally successful SMEs operating in automotive, mechanical engineering, electronics and chemical industries. The fourth industrial revolution in japan is different from all other states, because of the strong industrial base with a long tradition, one needs only consider that one of the most widely used value engineering method applied all over the world is the World Class Manufacturing coming from the Japanese philosophy.
However, the industry 4.0 offers advantages in all the sectors of the economy and for this reason the Japan is trying to improve through this project the manufacturing automation field, network technologies and smart production. One of the key point for the implementation program on the forth industrial revolution in japan is the standard implementation, it should be noticed that here there is not distinction between norms and standards, both them are covered by the term "hyoujun". This particularity in the implementation of the industry 4.0 makes the initiative an opportunity and a thread at the same time, as reported by 'Industrie 4.0 in a Global Context', "One challenge is the danger of multiple uncoordinated technological developments and standardization activities."[9] even if the government supports and purposes initiatives regarding this project.

[9] Industrie 4.0 in a Global Context – platform industrie 4.0

USA

The program of United States of America is the "Manufacturing USA" consisting in a partnership between government, institutes and companies in order to innovate the manufacturing plants and processes. It is based on nine manufacturing institutes spread through the all country and it is planned to add others six within the end of 2017. This program is based on training, research and development and new technologies and it aims to increase the manufacturing competitiveness of the companies of the United States. This project bets on high technology and creates a network between companies in order to get economic advantages and reduce the commercialization times. The particularity of the project is the distribution, because if in one hand the information and ideas are shared between the actors, on the other each engineering fields are maintained separated from the others by attributing to each one a dedicated institute. The final ambitions of the Manufacturing USA are establishing new institutes and collaborations, with the goal of establishing a community of manufacturers, manufacturing supply chains, workforce development programs, and technological centers.

Mexico

Mass medias do not cite Mexico as a big driver in the manufacturing sector. However, the Mexican manufacturing sector is very big and mainly oriented through the export, obviously the main customer is the USA. Unfortunately, in the past few years this important role of the Mexico is losing points and as a result the shear dividing the big multinational industries and the SME (Small Medium Enterprises) is increasing the gap between them. This trend has resulted in a two-speeds national economy, including the ability of implanting the technological revolutions inside the company. As rule of thumb, on one hand, the big companies are implementing the industry 4.0, while on the other hand, the SMEs are blocked to the second industrial revolution. Moreover, the difficulties in Mexico are not only linked to this two-speeds economy, but also to the reduction of requirements from exporting countries. Thus, the economy is decreasing mainly due to the less robustness of the demand from the US.

For all these reasons the ministry of economy and labor (Secretaría de Economía y Trabajo, SEDET) with the support of other stakeholders published "Crafting the Future: A Roadmap for Industry 4.0 in Mexico" defines Industry 4.0 as follows: "The cross-cutting impact of ICT, especially the internet of things (IoT), in various industrial sectors translates itself into a phenomenon that specialists have defined as the fourth industrial revolution: Industry 4.0 or I4.0."[10]. The final purpose is to revolutionize the industries transforming them into smart factories, with a greater flexibility in the production system, a higher level of integration and allocation of resources and a technological advanced monitoring of processes with the help of cyber-physical systems and Internet of Things technology.

The government has expressed its help through different steps, first of all, the awareness of the technological evolution in the final part of 2017. Additionally, the government believes the "creation of mini-consortia that will take the lead in developing Industry 4.0 applications in each field" as reported from Aguilar Valencia.

Finally, the economic support from the government is constituted by a fund of between MXN 100m ($6.3m) and MXN 120m ($7.2m) for implementing the industry 4.0 project.

Middle East

Middle East has been one of the first countries improving the concept of industries 4.0 inside its companies. In fact, the 41% of the companies interviewed by PWC declared to already have achieved an advanced level of digitalization and integration, moreover, over 62% are expected to

[10] Crafting the Future: A Roadmap for Industry 4.0 in Mexico – Secretaría de Economía y Trabajo, SEDET

be at such a level within five years.
These percentages are unusually higher if compared to the other countries worldwide. The aim of the companies implementing the project of industries 4.0 is more directed toward the service level, since it is still lagging, while the automation level is advanced. For this reason, the client service is the main objective, with the competitive differentiation and the integration between clients and suppliers in the processes.
The investment on the industry 4.0 is so important that, as reported by PWC, a company leader in the cable manufacturing has achieved an high level of integration and advanced digitalization by investing in the past years more or less the 10% of the annual revenues in implementing the technologies, including: vertical availability and integration of all development, effective data management and improved data analysis in real time, automaton of all important processes in a one-piece flow and continuous measurement and optimization of all process steps and parameters.

EUROPE

Manufacturing sector is a leader in the European economy, simply because of the countries specialized in this sector. Roughly, one enterprise out of ten works in the sector for a total of 2 million of companies and 33 million jobs. It is also estimated that the manufacturing field is responsible of over 80% of the exports and 80% of private R&D. Moreover, the manufacturing creates almost twice the jobs than other sectors.

However, the EU economy is declining during the recent years and losing one third of the industries founded in the past 40 years. The European Union reports a decline of the 1.2 percentage points since the beginning of 2008. Principally, this falling trend is due to the relocation of the labor-intensive activities moved to the regions where the labor cost is cheaper, but today the relocation in these countries does not produce the savings of few years ago. An example of what explained is the relocation to China. A decade ago the labor cost of the country was very cheaper, thus some big entrepreneurs moved their production plants there, particularly along the coast for reduce the logistic cost. After some years, unions and work force became aware of their rights and the costs for the companies rose. Thus, the production plants were moved to the backcountry for maintaining low the cost. Once again after few years the workforce understood their rights and the labor cost rose.

In 2012, for facing this trend, the European Commission sets the target that the manufacturing should represent the 20% of the total value added by the 2020, by boosting the productivity and stimulate the economic growth. However, as shows a survey conducted in 2013-14, there has been some inertia since the 88% of the interviewed said that they did not fully understand the business model of industry 4.0.

European union outlined five discussion points for the implementation of the Industry 4.0 plan through the community. Independently by the name and the policies applied by the country hosting the company, these guidelines are the same for all.

Investment and change. To achieve good results with this industrial revolution companies should cooperate with competitors. This is one of the reasons why the governments of some countries developed centers for exchanging ideas. Moreover, huge investments are needed, both from governments and ministers and from private companies.

Data owners and security. The large employment of IT technologies for treating large amount of data makes, in one hand, more dynamic the process of ideas exchanging, but on the other, the risk of industrial espionage or a utilization not authorized by the owner rises.

Legal issues. Employees' supervision is another threat. An example is the utilization of a 'smart glove' able to identify bar codes or QR-codes, however, the pace of codes reading can be interpreted as worker productivity.

Standards. As seen in the point regarding the data owners and security, the data exchange is a pillar of the project for the industrial revolution. Nevertheless, this leads to another problem, the communication. Two machines or a machine and an infrastructure communicating need to adopt the same standard and protocols. Moreover, one strongpoint of the 'smart factories' is the plug-and-play of the line's components, thus having the same standards is central in order to perform it.

Employment and skills development. The high automation pursued by the actors will lead to a change in the employees' skills required. In the non-decisions-taking jobs, the humans will be replaced by machines, but it is far from the human personnel that will become unnecessary. The human resources requirement will move to specialized workers, able to control and manage the machines throughout the line. It is estimated that in 2020 the European Union will be short of more than 800 000 ICT professionals. That is why initiatives for encouraging the acquisition of 'eSkills', especially from the schools.

The amount of money invested in the clast 'Industry 4.0' in Europe consistent. The plan consists in moving up to €50 billion of public and private investments for the digitalization. For boosting the digital innovation €37 billion are available, another €5.5 billion are at disposal to favorite the national and regional digital innovation hubs, €6.3 billion are dedicate to the first lines with next-generation components and €6.7 billion for the European Cloud Initiative.

Finland

Finns industries have put most of the effort through the Industrial IoT and as it will be detailed exploited, it is one of the key points of the project of industries 4.0.
However, an important company, FESTO developed the capacity of dealing with all the aspects of the plan. They will provide instruments regarding IoT, smart factories, cyber-physical systems and big data analysis. Moreover, FIESTO works in strictly contact with the German industries, hosting also meeting regarding the fourth industrial revolution. Also, the government has grater expectation about the industry 4.0, in fact the company TECHHUBFI reports "Industry 4.0 is just a starting point for Finns. Whether its data gathering, connectivity, analytics, planning or visualization, Finnish companies know their business."[11], this comes from the meeting in the Hannover Messe of March 2017.
Before the development of an industrial plan in Finland, in 2015, the industrial sector was losing points with respect to other countries, particularly in the seven years from 2008 to 2014. This negative trend would lead to a loose of 16000 factory jobs in the next four years. Thus, the government has decided to favorite the development of the Internet of Things, in a way as much strong to be defined as "Silicon Valley of the Industrial Internet" with the target of using the know-how, production and service investment in order to increase and create jobs.

[11] Finland goes just beyond 4.0 at Hannover Messe 2017 – TECHHUBFI

Sweden

The Sweden Government strategy for renewing the industry and strengthening both flexibility and the competitiveness of local companies is based on four focus areas: ***Industry 4.0***, Sustainable production, industrial skills boost (supplying industrial skills and promote the long terms development) and Test bed Sweden (leading research in areas for strengthening the industrial production of goods and services).

One of the most critical point of the production in Sweden is the tendency to move outside the country and to invert this phenomenon is not simple at all. In fact, even if the government continuously proposes incentives and flexibility in relation to customer demand, only 4% of the industrial companies have moved home the production with respect to the 17% of the companies moved aboard in the recent years.

For the purpose of industrial improvement, obviously, the public administration has a crucial role. Here the Sweden government has regulated the procurement. By providing opportunities to companies to test the new goods and services in real-world tests and demonstrative environments, leading the development towards more technological advanced products.

The particularity of the Sweden project is the strong integration of three characteristics that a company should develop: competitivity, sustainability and productivity. Obviously, these strongpoints should be pursued by all companies, but the Sweden regulations make a direct link between these in order to achieve the goal of creating jobs and contributing to local and regional competitiveness.

Competitiveness in the industrial sector of the country, as well as the others two fundamental prerequisites, in the business sectors are the roots for achieving the target of doing business and developing operations, through good framework conditions. For creating this stimulating environment, the public administration can resort to laws, regulations and taxes, but also to improve energy supply and infrastructures.

On the other hand, this project launched by public's initiatives has not practical effects if there is not participation from the industry and industrial services. That is why collaboration platforms and regional clusters have been proposed between local and regional administration and the companies.

Moreover, the European Union has an impact on the feasibility in the achievement of this strategy's targets.

The Minister for Enterprises and Innovation's is used as discussing and evaluating forum for the new industrial policies. The follow-up of the innovation plan is continuously updated. There indicators used for metrics for the adaptation and renewal capacity of the companies. The predominant ones are: employment in different parts of the value chain, productivity, gross investment and R&D investments. These are useful for giving a holistic view, in the near future (as reports national articles about the industry, 'A strategy for new industrialization for Sweden′) "it may become necessary to develop or supplement these indicators, especially for monitoring and evaluating the concrete measures in the action plan."[12]

Portugal

Portugal has a lot of expectations form the industry 4.0. Privileged companies are the small medium enterprises. The goal of the economical and development sector of the government is based on three exes: digitalization, innovation and training. These three pillars are followed by 120 Portuguese industries participating in designing a strategy in order to adopt this kind of revolution stated in the four main sectors in which it can boost the development: automotive, fashion & retail, agroindustry and tourism. The pillars on which the strategy is based are six and comprehends:

[12] Smart industry – A strategy for new industrialization for Sweden – Government Offices of Sweden

Human capital qualification. Emphasizing the concept of requalifying the workforce, adapting the education system to match the future industries' needs by integrating the digital skills from the educational curriculum. Nevertheless, it is important to encourage the employees to continuously enhance the training about extracurricular activities. The goal is to train 20'000 employees within 2020.

Technological cooperation. This is focused on the importance of integrating the technological suppliers, the scientific community and industry for promoting the cooperation, up to 24 measures are implemented for stimulating and encouraging the partnership.

Start-up i4.0. This pillar focuses on boosting the country to be central in driving the innovation, also making the country attractive for foreign investors and the tourism that is one of the central factors of the country economy.

Financing and investment incentive. The government is working through loans, tax deductions, call for proposal and vouchers in order to let to take a breath to the companies that try to implement the "Indústria 4.0"

Internationalization. This point recalls what said regarding the necessity of be attractive to the foreign investors. Nevertheless, the government works in order to let the small medium enterprises to expand their market out from the country bounds, in order to enlarge it and make the national SMEs international companies.

Standards and regulation. The last point regards the improvement of the industry by identifying the readiness of Portuguese regulations and standards.

Practically, the goal of this revolution is expected to impact on over 50'000 companies and train over 20'000 workers.
The government has budgeted an investment of €4.5 billion for the next 4 years. These funds are available through Portugal 2020 ERDF funds European Regional Development Found. Moreover, €2.26 billion are allocated for the adoption of technology and infrastructures linked to the concept of the Indústria 4.0: different financial tools will be used (loans, tax deductions, call for proposals or vouchers). For instance, there is a financial instrument called "vale Indústria 4.0", on which the government invests over 12 million euro distributed in vouchers of €7 500 each to support the SMEs' digital transformation.
The multinational companies play a central role in the program for the technological revolution in Portugal, Bosch will invest with Minho University €4.7 million up to 2018 for the additive manufacturing, additional €19 million will be invested in partnership with Aveiro University for smart houses and related equipment.

Great Britain

Great Britain has a lot of expectations on Industry 4.0. First of all, because of the decision of the Brexit, since this maneuver is having a big impact on the industrial sector. Additionally, the gap of the country with respect to the other countries in the center of the Europe for what concern the manufacturing activity is increased. However, the government and the Boston Consulting Group (BCG), the Great Britain is able to drive this industrial revolution like what has done with the first one in the eighteenth century. The companies of the country have to strength the competition, also considering the recovery actions the European Union will take against the Brexit.
From the point of view of the BCG one of the worst points for achieving the result of leader in this process is that the industries in the country have not followed the government in the revolution, there is a sort of inertia. In fact, according to the surveys of BCG only the 70% of the

industries all around the five countries composing the UK believe their companies is ready to implement the new technologies and only the 5% are willing to integrate the full concept of the industrial revolution.
This inertia maybe can be overcome by the advantages given by the implementation of this new concept. In fact, from the forecast of the BCG, the 4.0 in the United Kingdom will make the industrial production 30% faster and 25% more efficient, taking into account the additive manufacturing role in creating high-end components for the aerospace. the whole potential gain for the English companies is a cost reduction in labor, operations and logistic, that potentially can lead to a productivity increment of 5-8% by 2025, by investing 7-9% of the company's revenue. The input given by the government was the £400m invested in the 2016 autumn statement and the £1bn secured to boost UK broadband. These money over a total of £23 billion (from 2017 to 2022) are spent in the sectors critical for the productivity: housing, R&D and economic infrastructure. Moreover, the National Productivity Investment Found will spend £170 billion over the period from 2017-18 to 2021-22. The main ambitions of this investments of the government are to double up the capacity to support exporters through UK Export Finance and cut the taxation of the R&D.
Similarly, to US, the United Kingdom has also developed a network in order to improve the innovation, this is the "Catapult Programme". It is composed of world-leading centers aiming to transform the UK's capability of innovation by specific areas and drive the economic growth. The program comprehends 636 academic collaborations, 2473 industries involved, supported by 2851 small-medium enterprises and £850m of founds with open access for research and demonstration facilities. Most centers are in the center/south of the England, less there are in Wales and Scotland.

France

France Industry 4.0 was defined on April 26th, 2016 and called "Industrie du Futur". France has taken agreements with "Industrie 4.0" in Germany, by maintaining the focus of its own interest areas anyway. The project has been launched by the president of the republic François Hollande on 14th April 2015.
The enabling technologies on which the plan is based are four (rather than the nine suggested by Boston Consulting Group): Additive Manufacturing, Virtual Plant, Internet of Things and Augmented Reality.
The financing of this program is based on €305m in subsidiaries and payable loans under the PIAVE (promising industrial projects) initiative and €425m from the SPI (industrial project companies). Moreover, through the prime minister, Manuel Valls, the government has developed two exceptional measures to support companies: €2.5bn in tax incentives for companies investing in their production within the following 12 months and €2.1bn in loans for SMEs and mid-tier firms over the following two years (with the supplement of €1.2bn for companies investing in "industry of the Future" projects).
Another important aspect of the French program is the "employee training" that has not been widely employed worldwide. This aspect comprehends the upskilling of the industrial workforce and training the next generations for being prepared for facing the new jobs they will be in contact with, above all the digital and automation technologies in industrial plants. For these reasons, the national trade unions active in the National Council for industry (NCI) is part of the Industry 4.0 project in France. Particularly focus is oriented to the training aspect, through two dimensions: *A forward-looking dimensions* with the launch of interdisciplinary research programs for the role of human in the future and *An operating dimension* more concentrating on short terms where the formulation and implementation of initial ongoing training programs corresponding to challengers.
What explained above is only a first part. The Minister for the Economy, Industry and Digital Affairs, the second phase of the New Face of Industry in France program, is pursuing three objectives: More directly address the needs and the markets (pursuing a more holistic approach), Acquire a stronger international dimension (aiming to attract more investors in France) and More effectively manage the overall program (more responsive and faster program management for

facing such a dynamic market).
Finally, the French project outlines another crucial aspect of the industry 4.0 philosophy, the waste recycling. In fact, the reduction of the impact of the industrial wastes is one of the key points of the fourth industrial revolution and French Government has proposed solution in order to recycle the plastic and has put the incentives for it inside the program of Industry 4.0. The targets of the France are: 37% growth in the bio-based products market from 2012 to 2020, 3% of world plastic will be bio-based looking to 2015 (with annual growth if over 10% as of 2017) and 3.5 million tons of plastic waste per year in France.

Germany

The German's solution is "Industrie 4.0". Germany has been the pioneer of the idea of industry 4.0, with the congress in Frankfurt in 2011. Through the improvements given in particular by the Internet of Things and the Cyber Physical System, the willing of the German manufacturing sector is to improve its business processes, transforming the plant into Smart Factory. This concept is interesting because the consortiums that collaborate within the Industrie 4.0 project outline the concept of Smart Factory. OTTO Motors (German company developing self-driving vehicles and so born with the concept of industry 4.0) defines the 'Smart Factory' as "an environment where machinery and equipment are able to improve processes through automation and self-optimization. The benefits also extend beyond just the physical production of goods and into functions like planning, supply chain logistics, and even product development."[13]. The final goal of the industrie 4.0, is different from all other national plans about the fourth technological revolution. The reason is that the German manufacturing sector is the leader in its sector, so the plan to improve productivity, quality and cost is necessary in order to maintain the followers behind and its excellent international reputation. The standardization is one of the strongest points for dealing with the other countries and the government is aware about that. The direction follows a top-down approach, starting from the government, few big companies and a restricted number of researcher consortium and pioneering thinkers. The organization of the plan is similar to the one of the American manufacturer, following the idea of innovation centers (with collaboration with other countries, for instance France) driving the revolution and accelerating the commercial development process and reducing the innovation risks. The collaboration with foreign countries' innovation centers allows a more cooperation between strong business and economic growth.

Moreover, the 9 enabling technologies suggested by the Boston Consulting Group are modified in the German plan as "The 6 C's within Industry 4.0"[14]:

1) Connection; sensors and networks

2) Cloud; computing and on demand

3) Cyber; model and memory

4) Content/Context; meaning

and correlation

5) Community; sharing and

collaboration

[13] What is Smart Factory and its Impact on Manufacturing? – OTTO Motors
[14] Industry 4.0 - Germany

6) Customization; personalization and value

Government is part of the project with industries and academies. Particularly with the “Action Plan High-tech Strategy 2020”, that is the follow up of the platform insustrie 4.0. In this plan, the Government sustains economically the partners allocating founds of up to €200m and incentives.

Italy

The manufacturing sector in Italy has a central role in the national economy. Italy is the second country in the european union for this field, after the Germany. The geographical easy access to the commercial lines and the lack of availability of raw material moved the secondary sector to a central role in the national economy, followed by public and private investments that growth its potential give importance to the Italian market.

However, the relocation trend of the last decade reduced a lot the sector. The big groups moved their production plants to the countries with a lower labor cost and this hits the national economy a lot, maybe more than the other countries. This because the Italian economy has a market subdivision between big enterprise and family-run businesses very wide, as can be noted by the comparison in the following graph.

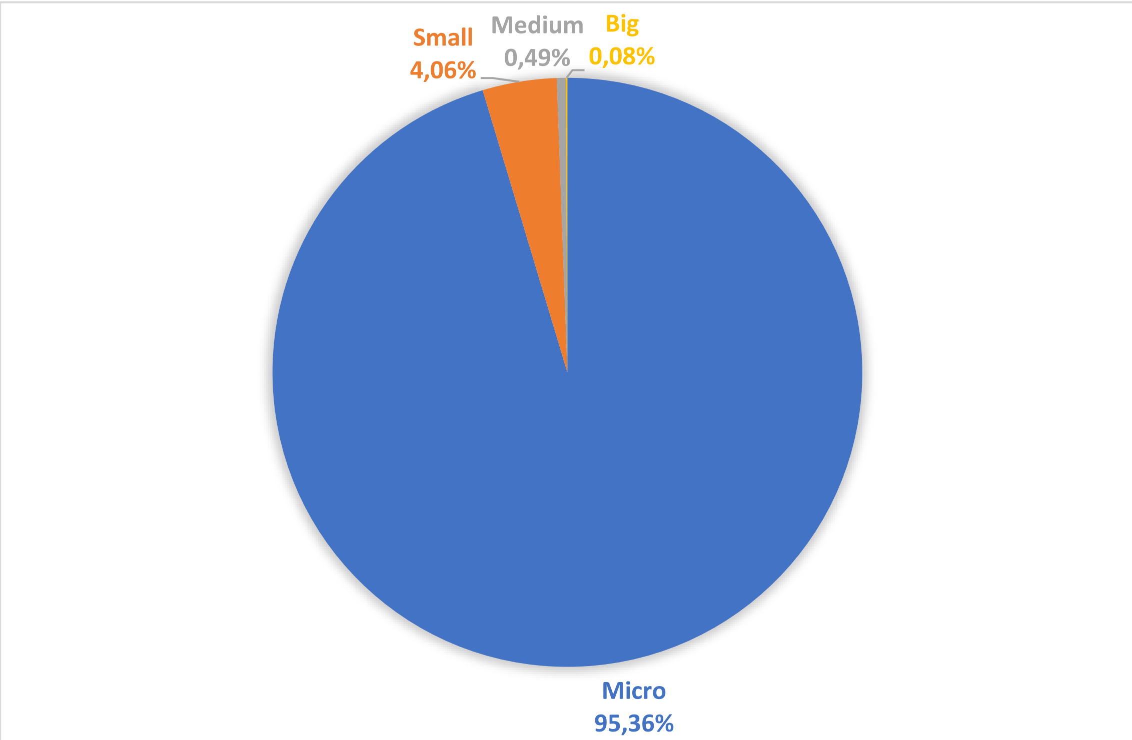

Figure 2. Distribution of enterprises in Italy – data from ATECO ISTAT

The relocation of the industrial plants made the manufacturing sector halved, especially in the occupation terms. The CSC (Centro Studi Confindustria) reports a reduction of more than the 15% of the potential of the manufacturing sector, with a peach in the automotive industry.

The government with the premier Matteo Renzi and the chief of the Ministero Dello Sviluppo Economico Carlo Calenda have published the plan industrie 4.0 inside the budget for the 2017.

In the budget, there is the target of placing private investments for about €11,3 billion in R&D and innovation.[15] These moneys are provided by incentives, connectivity and education.

The plan 'Industria 4.0' (this is the name of the Italian maneuver) is based on four strategic key points.

Innovative investments. It consists in stimulate the investment by the private entrepreneur in the qualifying technologies, innovation and R&D.

Qualifying infrastructures. Improving the security of the data and information is crucial as well as defining the standard for a good communication.

Knowledge and research. This key point aims to provide the tools and favorite the education both of blue and white collars.

Awareness and governance. Sharing the information and the know-how among the companies is essential for achieving good results, especially in the next few years. The public sector must favorite the information flows.

The measures provided by the government are different, here there are the most important (and up today the most effective).

'Iper And Super Ammortamento'. The goal is to support and encourage the companies investing in the new technology by operating a financial support for whom decide to adopt software and it systems in order to digitalize its productive process. These would go from the 140% to 250% for the technologies bought.

'Nuova Sabatini'. It supports the companies requiring bank's loan for new tools and systems, by providing collateral for loans between 20 000 and 2 000 000 euro.

'Credito d'imposta R&S'. This tool wants to reduce the difficulties in investing in the research and development.

'Parent Box'. This is a reduced taxation on the utilization of intellectual capital (patents, utility models, copyrights…) reducing IRES and IRAP (the first comes from the central government, while the second is a regional tax).

'Startup e PMI innovative'. The startups have a simplified taxation and less bureaucracy, and the same treatment is for the SME.

'Fondo Di Garanzia'. This is for helping the companies encountering difficulties in getting loans from the banks. Creating a public collateral up to the 80% of the loan, for investments both in short or in medium-long terms.

At today, it has passed almost one year from the application of the plan and Carlo Calenda (one of the two promoters mentioned before) drew a picture of the improvements:

The investments regarding the tools and systems has risen of 11.6%.

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[15] Industria 4.0: tutti i miliardi che il governo vuole "mobilitare" - https://www.economyup.it/startup/industria-40-tutti-i-miliardi-che-il-governo-vuole-mobilitare/

More companies have invested in the R&D.

€3.5 billion have been invested in the broadband connection.

In the first eight months, the ‘Fondo Di Garanzia’ has increased of 10.7%.

However, there are some drawbacks, first of all the delay in the definition of the competence centers.

At 21st September 2017 Mr. Calenda proposed the second part of the plan. ‘impresa 4.0’ (this is the name of the new plan) will take the place of industrie 4.0 and it is oriented not only to the hardware and tools sectors but also to the service providing, with big investments toward the digitalization.

Chapter 3. ENABLING TECHNOLOGIES

The implementation of the project industry 4.0 is based on enabling technologies. In this chapter they are described the nine defined by the Boston Consulting Group[16], on which the Italian plan "Piano Calenda" is developed. These nine technologies are: Advanced Manufacturing Solutions, Additive Manufacturing, Simulation, Horizontal/Vertical Integration, Internet of Things, Cloud (and Fog) Communication, Cybersecurity and Big Data And Analytics.

Advanced Manufacturing Solutions

The third technological revolution made place for the implementation of automated systems able to operate in an industrial environment such as robots and, even if very imitated, the cobots. These technology, especially in the manufacturing field are essential for improving the ergonomics of the workplace specifically for some tasks, like bulky material handling. The fourth industrial revolution tries to improve the utilization of that kind of equipment, increasing their flexibility and interconnection.

Additive Manufacturing

Additive manufacturing (AM) indicates all the activity able to build up 3D objects, and thus prototypes, by using a technique consisting in adding layer upon layer of material. The materials employed can be plastic, metal and concrete. In the near future will be possible to use even the human tissue.

The process starts with a computer developed CAD implemented in a 3D modeling software. After the conclusion and validation of the drawing, the file is sent to the machine equipment (including 3D Printing, Rapid Prototyping RP, Direct Digital Manufacturing DDM, layered manufacturing and additive fabrication), the software inside the machine equipment read the data and start to create the final object.

Nowadays this technology is widespread on all the industrial fields, both in the research and development and the productive sides. In fact, for example in the automotive or in the aircraft productive plants, some components of the final product are made up with this technology.

Augmented Reality

The augmented reality has been implemented in the recent years mainly for entertainment purposes, for example the Oculus Rift by Sony.

However, the last developments in this field have shown the possibility of implementing the augmented reality for the productive processes, in which the operator is able to interact with the work in progress through a device. Thanks to this kind of devices, the operator is aware of additional information and characteristics about the product and about the manual process execution. Often the equipment is composed of cameras (and similar sensors), a tablet and a central control unit (a computer) elaborating the information.

An example of implementation of this technology is the project developed by the Politecnico of Torino by professors Dario Antonelli and Sergey Astanin, "Enhancing the Quality of Manual Spot Welding through Augmented Reality Assisted Guidance". This project consisted in implementing the augmented reality in a productive step in which the operator has to perform different spot-

[16] *Embracing Industry 4.0—and Rediscovering Growth* – Scalabre, O., & Boston Consulting Group.

welds. Through the tablet mounted on the welding gun, the operator knows exactly where to perform the weld and the system is able to understand exactly if the spots have been performed and, additionally, the execution quality of the job performed.

Simulation

The simulation is a technology allowing to create and analyze, in a digital environment, prototypes of physical model permitting to predict the performances of the real world.

The very new opportunity of the simulation is that any kind of companies can perform operation of testing of their line, and not only the big players. This means that the small and medium enterprises are able to perform an accurate and detailed production layout simulation of the final product or even production plant in order to optimize their investment.

Horizontal/Vertical Integration

This enabling technology is oriented toward the company growing inside the market and in its economy of scale. It is subdivided in horizontal and vertical because this growth can be oriented in two ways:

- The horizontal integration consists in the diversification of the products and/or services presented to the customers. This process reduces the competition and allows to achieve new customers or market segments. Practically, this process consists in open new departments for producing new goods or providing new services that the company still not commercialize. Otherwise, for fastening up, the company can acquire companies of similar sizes.
- The vertical integration is oriented through the strengthening the contacts with the partners and, thus, focus the attention to the supply chain. Additionally, this strategic objective is oriented in reducing the production costs, capturing the profits both upstream and downstream and having access to the distribution channels, reducing the intermediaries. One of the ways preferred by the companies for achieving this type of integration is acquiring companies even before or after its position alongside the supply chain process.

Internet Of Things

Nowadays, internet acquired a central role in the everyday life inside and outside the companies, however, the adoption of this incredible tool has been limited to the communication between people. The Internet of Things has been developed exactly for overcoming this barrier, in fact, the main goal of the IoT is allowing the communication between human and machine and machine to machine, even in remote locations. It can be assumed a definition of the internet of things as a tool with the ability of creating a network of devices to gain and collect data from the surrounding environment. Another name of this technology is industrial internet, this is the name of the technology specifically oriented to the world of manufacturing.

Cloud And Fog

The industry 4.0 is mainly oriented to the implementation of the internet inside the companies. However, the adoption of internet gives some problems of computation and information share. Thus, the companies will need a hosting service, the cloud. It allows the companies to compute resources or storage them.

Moreover, the fog computing has to be thought as “a son” of the cloud. It takes the advantages of the cloud computing infrastructure, but deploying a computer hardware closer to the edge of the network. More practically, thinking to the cloud, the reader can image them in the sky, far from the ground, meanwhile, the fog is closer. This is the concept behind the dualism of the real cloud and fog and the cloud and fog computing. IDC estimates that the 40 % of the data computing is at the level of the IoT[17], so the fog computing permits a lot the reduction of the latency.

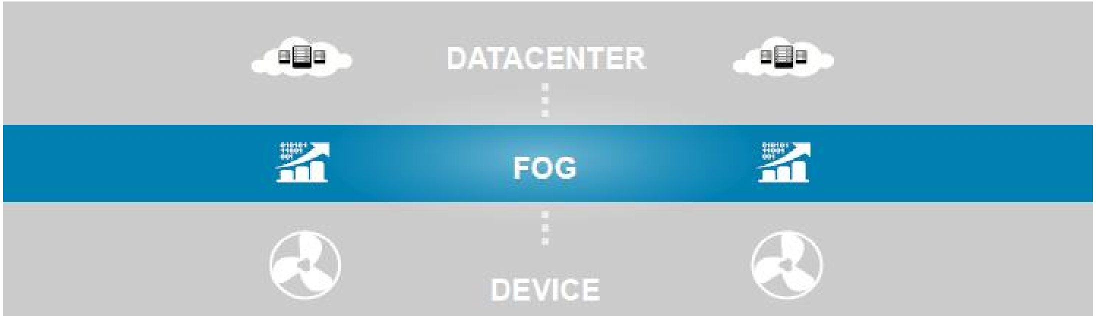

Figure 3. The Fog Extends the Cloud Closer to the Devices Producing Data – image from The Fog Extends the Cloud Closer to the Devices Producing Data – CISCO

Technically, the fog interacts directly with the IoT data and the things connected, with fog nodes. The importance of the fog computing is also related to the ability of the technology to be employed practically everywhere: power poles, railway tracks, vehicles, etc.

Cybersecurity

Cyberspace is an environment in which the risk of data stealing and hazards are likely to happen. The latest researches forecast for the 2018 stealing of data for something about 2.1 trillion dollars. Thus, cyber actors are developing solutions for outlining the vulnerabilities of the cyber systems and steal money and data. These thefts lead to the disruption or threaten the delivery of services. This happens against both the countries and private companies.

The problems in protecting the cyber space are due to high number of actors, widespread in the world and the difficulties in reducing the vulnerability in such a complex network.

On the other hand, the growing importance of the internet has made it essential and irreplaceable in the business, thus the protection of the cyber infrastructure is vital for the world market environment.

Big Data And Analytics

The data collection in the enterprises is not a new concept at all. However, until the recent years the companies had no idea on how the data collected are referred to and how to employ them.

[17] Fog Computing and the Internet of Things: Extend the Cloud to Where the Things Are – CISCO

Nowadays, the data starts to show the ability of adding value to the business by which they are employed. For this reason, as reported by Avantika Monnappa at 5th October 2017, “more than 2.7 zettabytes of data exist in today’s digital universe”[18].

In data science processes, this huge amount of data combines statistics, mathematics, programming, problem-solving and captures data in ingenious ways.

The big data are an enormous amount of data that cannot be analyzed by traditional tools. The main characteristic of this kind of data is the ability of use them to forecast the market environment in order to lowering the margin of risk in the decision phase. They can be employed for business (as said in the business strategies), e-commerce (the purchase data gathered by online shops helps to improve the customers aftersales services), finance (data on accounts, credit and debit transactions), government (monitoring the overall satisfaction and for a better security thanks to the identification), social networking (for targeting the advertise, improving the user satisfaction, establish trends, etc.), healthcare (medical recording in order to improve the prevention, vital for some pathologies), telecommunications (to forecast and prevent bugs), manufacturing (reducing the processing flaws, saving time and money), etc.

[18] Data Science vs. Big Data vs. Data Analytics – Avantika Monappa

Chapter 4. INTERNET OF THINGS

Gartner. defines the Internet of Things as “the network of physical objects that contain embedded technology to communicate and sense or interact with their internal states or the external environment.”[19]

The internet of things has been firstly introduced at the end of nineties, 1998 1999, by Kevin Ashton. It became widely used since the early stages for the auto-id and the radio-frequency identification (RFID). However, for the next decade this technology has been stuck to these few applications.

Nowadays, IoT has taken its role between the other technologies thank to the idea of smart industries and the technology embraces several developments, as disjointed as they are numerous. The basic idea is considering it as built of “interconnected smart objects” and concentrating the interest towards the communication technologies, developing the way in which this connection is established or else considering the “smart object” perspective. The last one is oriented to the energy harvesting, conservation and the dimension reduction of components and printed circuits.

Zero-Entropy systems (energy harvesting, conservation and usage). It is a challenge for the future, developing a device able to harvest energy from the surrounding environment and do not waste it during its working cycle.

Scalability. The number of interconnected devices forecasted for the near future (5 10 years) is enormous. Their organization can be exploited in two ways, the first through a mesh and the second hierarchical. The second one is considered the most efficient for hosting such amount of connections.

Security and Privacy. The issue of having sufficient security on devices as well as technological architecture preserving the privacy of the user must be employed as basis for developing any future device.

Communication Mechanism. The communication has a central role as can be noted from the history. At the beginning of the internet there were a lot of communication mechanism and only the convergence on a reference one allowed the development of the web.

Integration of smart components into non-standard substrates. From the environmental point of view the development is pursing the possibility of building up components with non-silicon material, in order to eliminate both the dependency and the problem related to the silicon utilization (like packaging and recycling).

Theoretically the distinction from the “traditional” internet and the internet of things at protocol level lies in the idea that internet has an “end-to-end” principle. This kind of protocol makes the network faster by keeping the network simple and lean, while dealing the complexity at the end points only. This cannot be used for the IoT because there are two kinds of end points and no one is feasible for this architecture. The first type comprehends the sensors working in real time, for instance the wireless braking system for the automotive field. These assignments cannot be guaranteed by a best-effort, connectionless, unreliable protocol. The second type of devices is too cheap to use complex protocols such as IP, an example can be a passive RFID tag.

The internet of things is based on the concept of connecting every device with an on/off switch together and to the internet. It includes both devices we use in our everyday life (i.e. Cellphones,

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[19] IT Glossary – Internet of Things – Gartner.

coffee makers, washing machines, headphones, lamps, wearable devices) and devices employed in the industrial plants (such as mills, drills, lathes, automatic charts).

The growing importance of the IoT is due to the increasing of smart objects that a person will have in the next five years. Gartner. Forecasts that by 2020 there will be over 26 billion connected devices (some even estimate this number higher, over 100 billion), from the annual reports at today the world is populated by 7.6 billion people and the estimation is about 7.8 billion people in 2020.

Finally, according to the financial magazine Forbes, the impact on everyday life of people will be enormous. The alarm connected with our mobile phone and coffee maker, in order to wake up, find a hot coffee and the have the fastest driving directions.

Microsoft Solution For The IoT

SENSEI[20] project is a development environment thought for integrating the physical and digital world, mainly throughout wireless devices. It was developed by Microsoft that puts all the efforts in order to apply the best practice acquired to a software able to integrate innovative technologies into the business process and optimize the investments.

Examples Of Development Fields

Automotive

The car-to-car communication consortium aims to provide communications vehicle-to-vehicle (V2V) and vehicle-to-infrastructure (V2I). This initiative has started internally in the European vehicle manufacturers, but today it is open to new partners. The architecture is based on the multiple Road Side Units (RSUs), consisting in devices acting as gateway for vehicular On-Board-Units. Vehicles identifiers, as well as location identifiers are based on IPv6 addresses owned by vehicles' OBUs.

IPv6 is an internet protocol developed for the memory storage in countries with big population, like India or China. It is an improvement of the IPv4, by an enormous increase of the number of addresses, from 2^{32} to 2^{128}. This technology has been also integrated in the IoT system for the big memory capacity, it has been preferred to the IPv4 because of the requirement for connecting many devices in order to translate the physical environment into the digital world.

Pharmaceutical

There is a lack of harmonization and standardization in the pharmaceutical field. In fact, inside the European community the codes used to identify a pharmaceutical product change from country to country, only few and little group of country use the same codes. IoT will aim to harmonize the interchangeability of these codes between countries. Moreover, the high communication speed can increase the possibilities of meeting the requirements from the population in order to ensuring the right drug with the most suitable specifics for the patient. Some examples are Whytock (Siemens), Bottomley (Rockwell), Winkler (Honeywell) or Topp and Gruner (ICONICS).

[20] SENSEI – www.senseiprojectsolution.com

Architecture Reference Model For The Internet Of Thinks

The reference architecture of the IoT is based on 4 strong points:

Vision, it is a summary of the characteristics for a reference model of the IoT. At the same time, it underlines the assumptions and the targets. It also presents the alternatives on how the model should be used.

Business Scenario & Stakeholders. These are the drivers of the architecture, giving the idea of the business aspiration and having a holistic view of the project the IoT.

IoT Refence Model. This is the higher abstraction level for the definition of the final architecture, it gives a top-level description and a gross disclosure of the IoT domain. From these can be pointed out the communication model and the interaction schemes for smart objects.

IoT Reference Architecture. This is the final step in order to build the IoT architecture, considering the stakeholders requirements.

While the reference model defines the language to be used, the reference architecture prescribes the minimum requirements of the system.

The reference architecture is a matrix giving all the concrete architecture for the IoT systems. Starting from the set of all possible functionalities, mechanisms and protocols used for building such structure is possible to show how interconnection could take place. Benchmark is an important tool for developing an architecture. The following figure explains that in a graphical way.

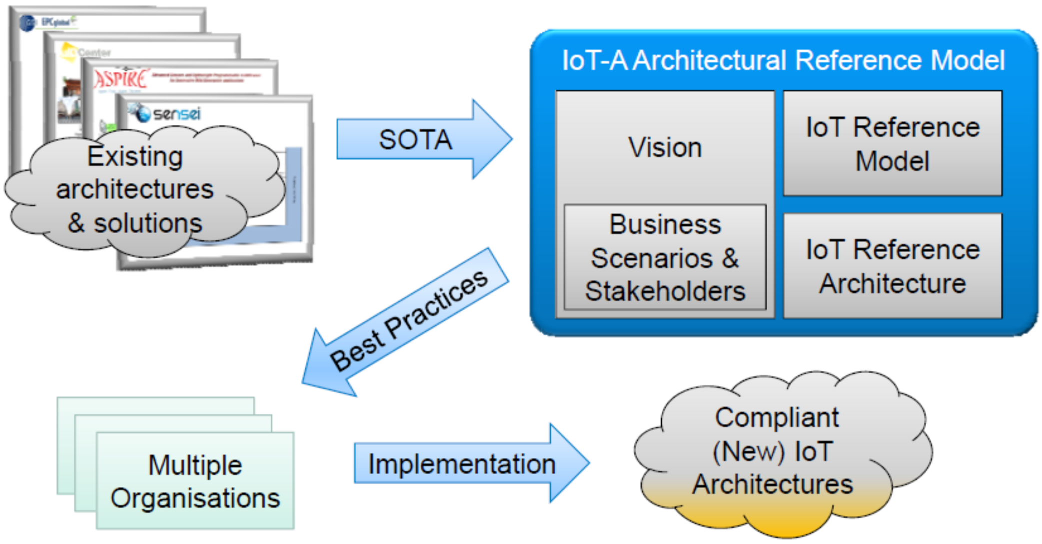


Figure 4. IoT architecture reference model – Internet Tools and Services - Lecture Notes (Dr. Attila Adamkó, 2014)

As base for the reference architecture there are four steps:

functional, defining the system's runtime functional elements and their responsibilities

information, managing and distributing information

deployment, describing the environment in which the system will be employed operational, describing how the system should work and administrate.

Moreover, the IoT reference architecture focuses on four characteristics:

Security and Privacy, analyzing the security treads and explaining how the privacy is protected.

Performance and Scalability, defining how many devices, services and processes the system is able to manage.

Availability and Resilience, the ability of the system to be operated and how the failures are managed.

Evolution and Interoperability, the flexibility of the system after the deployment and the ability to exchange information between two or more different systems.

The IoT system works with two different protocol for the data exchanging, both use internet protocols:

REST. The RESTful system is based on HTTP and URLs protocols. This protocol is aimed by the idea of the resource. Thus, it gives to the client the link to the resource in which the service required is stored.

SOAP. This protocol is based on XML and it adopts an internet protocol for the data exchange, for example the HTTP. This packing technique works with the idea of service, providing to the client the direct link of the service required.

These two methods are low level services. Services are exposure of heterogeneous resources and are composed by many interfaces and protocols. They provide a well-defined and standardize interface between the source and the client, hiding the complexity of the whole system.

Business Scenarios

Application fields of the IoT structure are very wide. In order to give an idea of such incredible technology here there are some examples.

Transport and Logistic. Though the information exchanging between all the actors of the value chain the IoT can improve not only the material flow but also the positioning and the auto certification of goods. Moreover, the balancing in the material flow will lead to a better utilization of the resources and so to a reduction of energy consumption. Furthermore, the information flow makes the supply chain more transparent and visible to the final customer.

Smart Home. The impact of the IoT in the homes is forecasted to impact on three aspects: the resources usage (electric and water consumptions), the security (security systems for theft, unauthorized accesses or in case of fire) and the comfort.

Smart City. IoT is believed to improve the live inside the cities with a sustainable development and high-quality life, examples can be infrastructure for charging electric vehicles or remote patient monitoring (i.e. diabetics).

Smart Factory. In this area the improvements are countless, from the trackability of the products through the RFID to the production control and automation. Coupled with the robotic, this technology can reduce the more repetitive work and, at the same time, it increases the opportunities for the specialized employees both for the managing of the machines and for the maintenance.

Retail. Integrating the interests of the customers and businesses, the IoT can compare the products, the prices and the quality, in this way the small shops are able to decide on reliable data which products buy and put on the shelf.

eHealth. In these last years, medias have talked a lot about the possibilities of wearing devices connected with specialist in order to screen the health of the person wearing it and move the healthcare from reactive to proactive. Moreover, the device can maintain in memory the clinical history of the patient, details crucial for the medical evaluation.

Environment. this application field overlaps the two before described about smart cities and smart homes, thus, here will be described only the characteristic of energy saving. This target can be perceived throughout the Smart Grid. It is a distribution method for the energy by taking into account the private sources of energy that the houses have today, in particular the solar panels, by intelligent monitoring and the communication: the citizens have a more direct control on their usage of water and energy, the administrations have a stricter control on the usage and the detection of out of service, so a faster restoration, and finally it reduces the need of new plants for the power generation.

Devices Of The IoT

Deployment

From the deployment point of view, there is a distinction of the resources based on the proximity of the action:

On-device resources are deployed locally on the devices themselves.

Network resources are deployed externally to the device, with a remote interaction with the device over a network.

Example Of The Utilization Of The IoT, Services And Sensors

Here is reported an example of an employment of the IoT technologies. Obviously, the field where to engage the IoT is many, the one reported below is a simplified case in order to give a basic idea on the functioning characteristics of this tool, especially in a logistic environment for pointing out the benefits coming in a case recalling what mentioned before, talking about the adoption of automated system for the logistic aspect.
The utilization of a sensors network in order to monitor the perishable goods in a store. More precisely, the sensors are used to measure the quality of a rare expensive form of Chinese orchids, by considering luminance, humidity and temperature of the environment. Thanks to the combination of these factors, the automated estimation of the future quality of the precious flowers degradation and the market price, the system is able to ensure that the goods are sold before a quality reduction.
Below is reported a scheme of the whole sensors, central control and accounting system used.

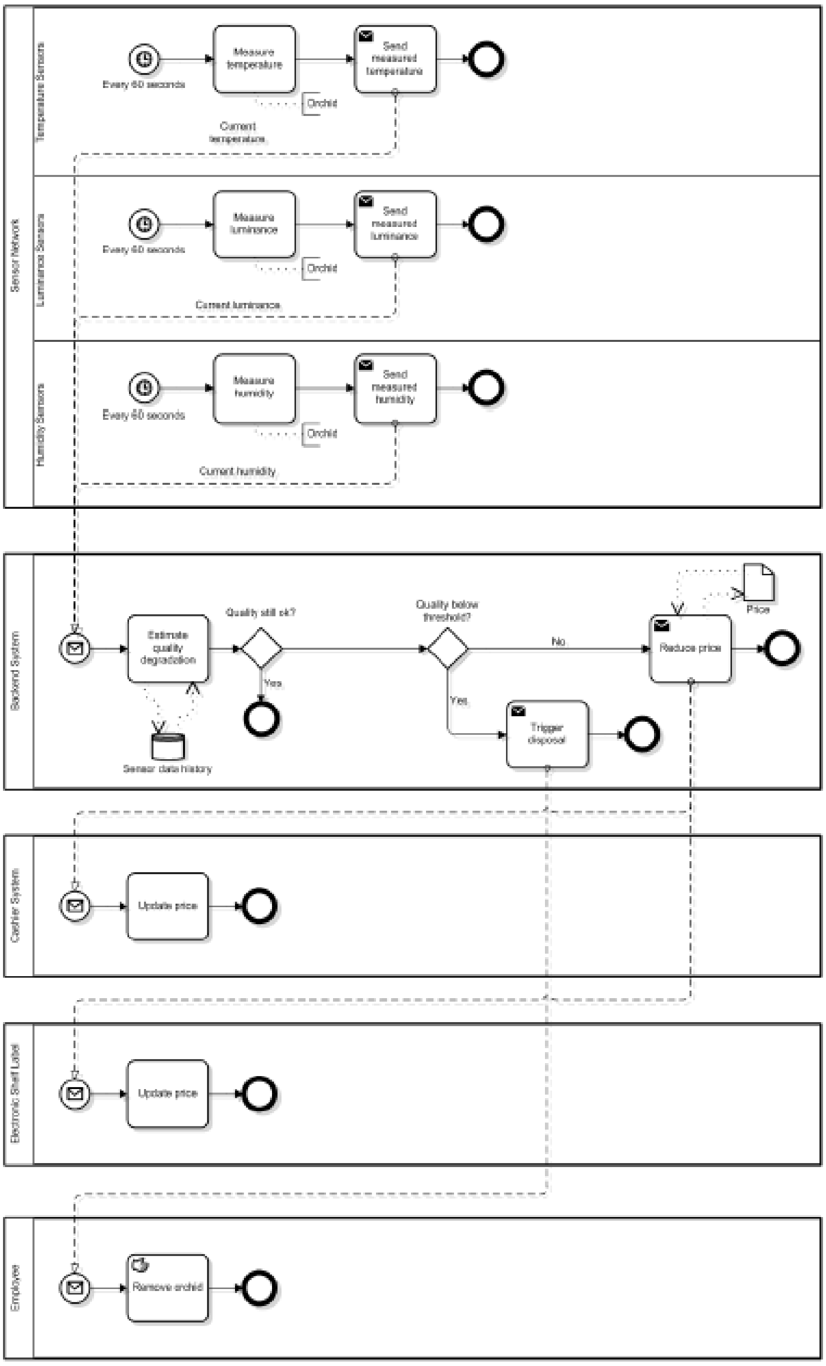


Figure 5. Extended sensor based quality control (Hagedorn et al. 2011) – IoT-A, Spyridon Tompros (CSE), Werner Liekens (ALU-BE), Konstantinos Koutsopoulos (CSE)

Advantages:

Sensors are very simple devices and cheap.

Sensors dimensions are small thank to their technical simplicity.

Threshold value for the environment and price calculation are very flexible and can be varied in of storage of different products (e.g. flowers in this case).

In case of other requirements, additional events can be added.

Disadvantages:

The continuously transmission of data leads to a constant increasing in network traffic.

The backend system is necessary for all the computation and through all the phases of the system lifecycle. However, if the computation or the thresholds change a lot, the system cannot be suited and so it must be changed.

The complexity of the computations of the backend system can drive to a limited scalability for the burden in the central elaboration engine.

The continuous calculations lead to a high CPU and memory load of the backend system, resulting in a reduction of resources available to other activities.

Services Classification

As the services that are provided in the physical world, also the IoT services can be classified by their "tangibility". In fact, there are three categories of services according to their level of abstraction:

Resource services expose the functionality of a device by accessing to the resources, controlling also accessibility, resilience and performances.

Entity services allow to learn (read) and manipulate (update) the status of the entity, by giving the access point.

Integrated services are a cross between the resources and the entity.

One of the biggest problems in the IoT resources is the employment of entity service of low level, managed by the above described REST and SOAP protocols. Their description consists in the static behavior of the physical environment while, for the characteristic of the real world, the description should be enriched in a way that the content of the service description is sufficient to serve as a basis for discovering the look-up of the relevant service and their association. This can be achieved by the Work Package protocols (WP). The WP are six.

WP1. This is responsible of the infrastructure and sensors composing the IoT architecture, it is the base for the scientific WP (2, 3 and 4) and verifies the feasibility of the algorithms development.

WP2. It oversees Context Aware Data Processing and Reasoning, by interpreting the data coming from the sensors.

WP3. The third work package checks the Semantic Models and Ontologies. In other words, it examines the coherency and consistency of the models that express information about customers and it also verifies the semantic content of the sensors, observations and measurements.

WP4. Configuration Planning. This package is important because it manages the sensors description, thus it defines the level of the acquisition devices and allows the "translation" of the physical environment into the digital world in a more precise way.

WP5. User Evaluation and Testbedding. This WP overviews all the previews described packets to ensure the consistency and at the same time defines if the scientific innovation is deployable.

WP6. Management and Dissemination. This can be thought as a report of all the others. It contains the scientific and administrative management of the project. Moreover, it includes the resources available to the management team, like visions and goals.

Modelling Approaches

In order to organize an IoT process, the guidelines are given by the Design Science (DS) Research Methodology for information System Research of "IoT-A Project Deliverable D2.3 – Orchestration of distributed IoT service interactions", by S. Meissner. It is based on the information technology research methodology, giving guidelines for evaluating and interacting between projects.

This DS is defined by four actors: business process, business process management, business process modelling and execution. Here they are expanded one by one.

Business Process (BP). According to Weske in "Business process management: concepts, languages, architectures" the Business Process is defined as "A business process consists of a set of activities that are performed in coordination in an organizational and technical environment. These activities jointly realize a business goal. Each business process is enacted by a single organization, but it may interact with business processes performed by other organizations."[21]

Business Process Management (BPM). This is a systematic approach aimed to reduce the human error and miscommunication, by focusing on stakeholder's requirements. It makes the workflow more effective, efficient and able to fit to a dynamic environment. A very detailed definition is given by the European Association of BPM in "Business Process Management Common Body of Knowledge - BPM CBOK: Leitfaden für das Prozessmanagement: Verlag Dr. Götz Schmidt", it is "a systemic approach geared to capture, design, execute, document, measure, monitor and control automated as well as non-automated processes in order to meet the objectives that are aligned with the business strategy of a company. BPM embraces the conscious, comprehensive and increasingly technology-enabled definition, improvement, innovation and maintenance of end-to-end processes. Through this systemic and conscious management of processes, companies achieve better results in a faster and more flexible way."[22]

Business Process Modelling. This tool is used for mapping the workflow, in order to understand, analyze and make positive changes to that. These representations can be graphical or non-graphical and the process model is an initial step for progressing with the other steps in the BPM lifecycle. This is crucial in the businesses because the result of capturing a business process is gathered by a process model. There is a distinction between two modes for this modelling phase:

- Business Level: it is based on a result-oriented methodology and an operational representation of the process. It begins with a rough understanding on the process flow.

[21] Business process management: concepts, languages, architectures - Weske

[22] Business Process Management Common Body of Knowledge - BPM CBOK: Leitfaden für das Prozessmanagement: Verlag Dr. Götz Schmidt

This is particularly useful for the integration of the operational details of the activity stream. The procedure for this process depends on the modelling language of the process.

- Technical Level: in this step, the technical details are implemented in the final project, creating the final technical process and for the execution a so-called process engine can be used. The Business Process Engine is a software framework used to oversee the project integration, interlinking and interprocessing. It works with all the different application infrastructure layers (front end, middleware, backend and external business applications), moreover, it facilitates the integration of their processes, inter and intra system communication, process data routing, data transformation and merging. Finally, it provides business processes interaction and communication between different data/process sources spread across one of more IT applications and services. The process engine is necessary since the project execution does not run automatically. This tool allows the representation of the process logic and it is more productive in the process implementation. Software solution for making the process engine more versatile became crucial, as well as separated service bus, and this raised the ability of the engine up to have a complete overview of the activities' execution.

Business Process Execution. It consists of the manual, semi-manual and automated execution of the BP. For the automated execution, there is an important precondition, the model of the technical analysis developed by the technical specifications.

Business Process Vs Services

Today, all the businesses from the largest international brand to the smallest shop in town have adopted an automated system for accounting invoicing and bills. However, not all the actors composing the markets have understood the advantages coming from the total adoption of an automated system, also for the ordering phase. Thinking about the chain collecting the manufacturer to the final customer, it is usually composed by logistic, distribution network and retailer, where the final customer buys and take the product home. The automation is believed to make this process more seamless, integrating the so-called smart items or smart objects. This can be possible thank to the IT technologies, allowing the more information sharing, thus the possibility of delivering the orders in advance and so starting the logistic earlier, in order to make faster the total delivering time.

How do the business process is linked to the concept of services?

Services are tasks over internet playing a crucial, and growing, role in the business-to-business interaction (as suggests Weske). Web services are the current realization of service-oriented computing, these web services can either be used in process orchestration, for instance, for exchanging messages between business partners over the internet. Instead, the business process is driven by a Business Process Engine (Technical Level) or a workflow management (Business Level) and the automated tasks in the business process are also implemented by web services. Thus, the services can be thought as a method for the implementation of the business process.

Machine To Machine

The communication between machines (M2M) has a central role in the IoT, because of the roles of machines in the endpoints. Thus, it makes possible the remote communication between them. These endpoints are characterized by varying complexity ranging from tags, sensors and actuators (wired or wireless), these mixed inputs and outputs of the IoT system have made necessary a unification of resources. This “standardization” between endpoints flows the M2M communication concept is able to communicate information from a machine directly to the central system or to another machine, providing a real-time data exchange.

By deeply analyzing the M2M communication, there are two kinds of communication frequency: event-based (working in case of particular events) and polling based (taking place in predefined time intervals). Furthermore, the M2M communication is composed of:

- data collection
- data transmission over a specific communication network
- assessment of data
- remote communications of actions on end devices

In order to organize the communication between end points and central IoT system, the Machine-to-Machine Application Programming Interface (API) is used. It provides the abstraction layer necessary to realize interaction between IoT devices uniformly.

Contrary to what the name can suggest, the M2M communication is believed to be part of the everyday life of the people all around the world and not only linked to the industrial business automation. Since some year ago, the development fields of the M2M communication within the IoT are building automation, industrial automation, security, transportation, healthcare, smart energy, smart grid, supply and provisioning, logistics, and city automation. Before to go in datils of some of these applications, it must be analyzed the three different forms of communication of the M2M, wired, cellular and capillary. The *wired* has the highest reliability and data rates but it is expensive and not scalable. *Cellular* protocols have good coverage but also a high energy consumption and high costs both for roll-out and maintenance. *Capillary* is the most cost-effective solution, scalable and with acceptable energy consumption, but the coverage is weak. For overcoming the drawbacks, hybrid solutions are in development phase.

HOME AUTOMATION / SMART HOME /COMMERCIAL BUILDING AUTOMATION
DESIGO commercial building automation systems, developed by SIEMENS. It provides scalable solutions for HVAC for commercial buildings like airports, hotels and shopping malls. Home Automation Europe. It provides solution for home security, monitoring, power consumption and home control.

MEDICAL APPLICATIONS
Alcatel-Lucent TeleHealth Manager. It offers a health monitoring with medical alerts and secure access to data collection, using Bluetooth technology.
Google Health is an application for organizing, tracking, monitoring and acting on heal information. The sensor technology is not yet specified.

DEFENSE APPLICATIONS
Obviously, the M2M in the defense is centered on the monitoring and controlling assets in remote locations, emergency management, search & recovery and disaster recovery situations. In this field, it is only provided a M2M application development platform, that can be customized according to the requirements.

ENVIRONMENTAL APPLICATIONS
As for the defense industry, the environment-related M2M products are platforms that then are tailored to the target applications. However, in this area there are sensors for monitoring the environmental conditions and actuators for reaching the user-defined conditions.

Architecture And Protocols For M2M

M2M FUNCTIONALITY AND REASONS FOR THEIR INTRODUCTION

The M2M functionality and its associated APIs protocols are required for satisfying the user demand for devices' functions and users' services. The interface network between user and device's sensors is composed by four parts: user application, service, M2M communication and devices. The deployment of these four actors is spread on a constrained and an unconstrained part, depending on the characteristics of the M2M functionalities. However, the M2M functionality cannot be totally decoupled by the unconstrained network, thus a constrained cloud is employed.

The logical separation between the two different functions (M2M and service) is managed by a generic application-level programming interface. The need of specifying that the programming interface is generically necessary for allowing a crossing point between all kinds of machines, without constraints due to incompatible programming language. Below it is reported a scheme of the interface between service API to the network communication and the API to the machine devices.

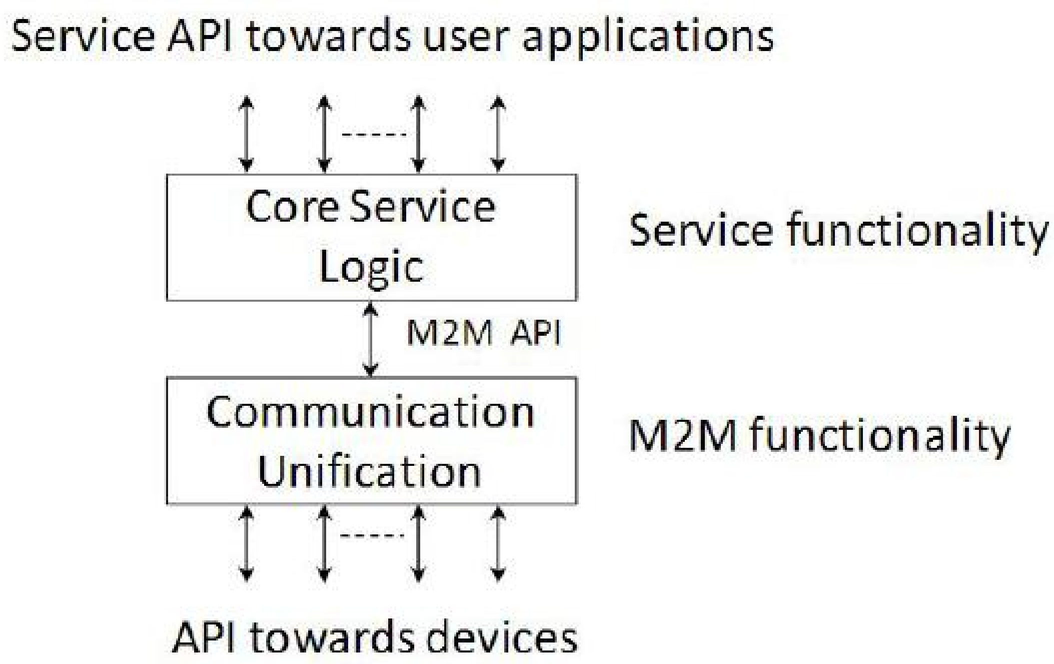


Figure 6. logical separation between the M2M functionality and the services – IOT-A, Spyridon Tompros (CSE), Werner Liekens (ALU-BE), Konstantinos Koutsopoulos (CSE)

Architecture Of A M2M Communication Interface

Here there is the description of the architecture of the M2M functionality and its supported operations. Starting with a total scheme and after developing the point one by one.

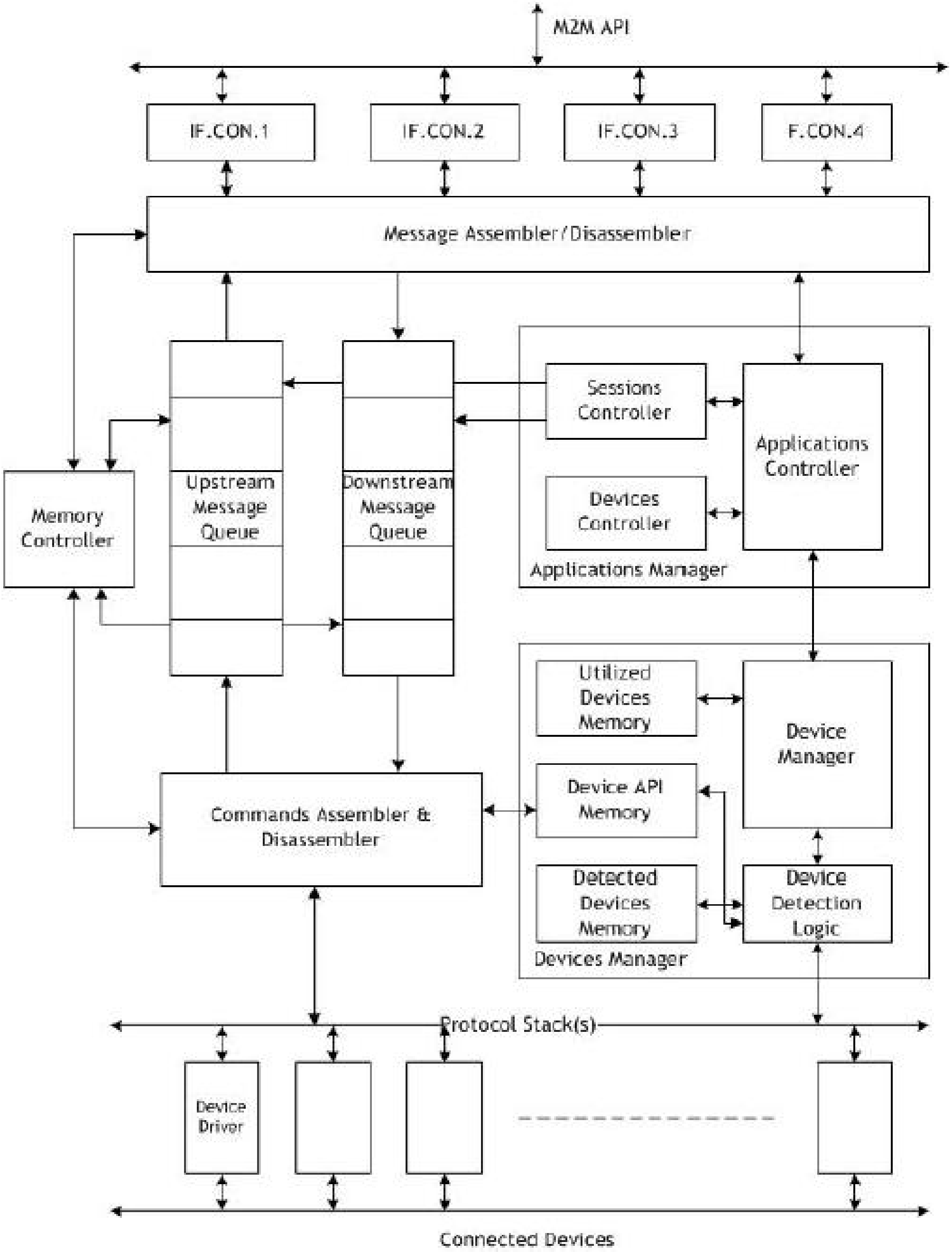


Figure 7. Internal architecture of the M2M functionality – IoT-A, Spyridon Tompros (CSE), Werner Liekens (ALU-BE), Konstantinos Koutsopoulos (CSE)

In the upper part, there are the modules for implementing sending and receiving functions according to the requirements (i.e. IF.CON.1, IF.CON.2, IF.CON.3, IF.CON.4) from the M2M communications protocols.

The step assembler/disassembler is necessary for break down the incoming packets and built up the outgoing packets of messages.

The application manager organizes the communication in the context of user applications. These communications are defined by information of application, sessions and device ID associations. These device ID created and maintained by the application controller, with the support of session controller and devices controller.

Device manager oversees the functionality related to the management of connected devices, including detection and registration of a new attached device. This management is comprehensive of implementing function, such as device enumeration, information handling and registration with the user applications. Inside the utilized devices memory is managed the association of available devices and user application for exploiting them. Device API memory stores the API information of the discovered devices, for messages receiving or sending to the connected devices. Discovered devices memory contains information of the devices detected in the local network, once the device is detected the API memory stores starts the association and the communication. Device discovery logic defines the logic of the device once it is plugged in the network.

Message queues are subdivided in upstream and downstream buffers, used for message storing and exchanging between user application and devices. They are both controlled by the queue controller providing management based on the information coming from the applications.

Command assembler/disassembler. This part is necessary for the compatibility with the devices APIs. For carrying out this task it takes the device API information stored in the Device API memory.

Security

The security has a central role in the IoT. Going in detail, the common aspects are the integrity of data and the trust in the service offering the data. Additionally, to protect the confident data is essential to gain the user faith and ensuring the privacy is crucial.

The cyber security is one of the nine milestone technologies for the industry 4.0. For this reason, there are some important data about the internet security. Reporting the data of CLUSIT 2017, the cyber-attacks of phishing and social engineering are increasing of 1,166%[23]. Moreover, according to the research “Data Breach Industry Forecast of Experian”, “the potential cost of breaches for the healthcare industry could be as much as $5.6 billion annually” and Juniper, in his report “The Future of Cybercrime & Security: Financial and Corporate Threats & Mitigation” alerts “Data breach costs will soar to $2T”. Finally, according to the Gemalto releases findings of 2016 Breach Level Index “[…] 1,792 data breaches led to almost 1.4 billion data records being compromised worldwide during 2016, an increase of 86% compared to 2015. Identity theft was the leading type of data breach in 2016, accounting for 59% of all data breaches.”[24]

Effectiveness Of IoT

The internet of things is an external factor influencing the company equilibrium both inside and outside. Inside with improvements in the production plants, workers environment and time to market. Outside because the competition will be more strict and tight, with the emerging countries

[23] PRIVACY RULES – privacyrules.com

[24] Data Breach Industry Forecast of Experian – Experian.com/2017-data-breach-industry-forecast.html

penetrating in the older and stabilized markets with products at lower cost and at the same, or maybe, higher quality.

Starting from the principle that none of the industrial environment in the nowadays market will be immune from the IoT revolution, automotive, energy, telecommunications, retail, banking and insurance, transportation, agriculture...
The consultant group KPMG outlined six principles for creating value from the IoT.

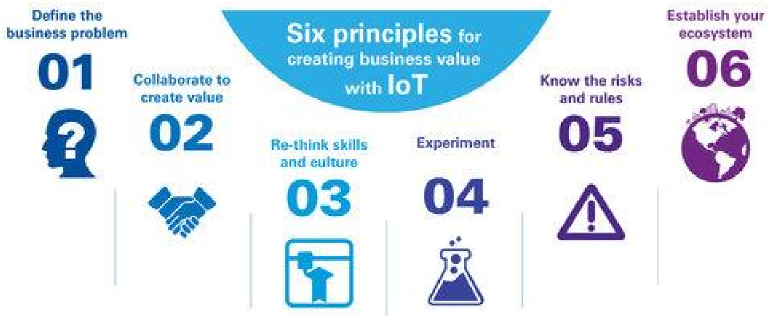


Figure 8. Creating values from IoT - image from KPMG

Define the business problem. Define the target of the utilization of the IoT, in terms of cost reduction, customer experience, quality, productivity, growth, product improvements or risk reduction.

Collaborate to create value. The key point that is reported quite everywhere when talking about the IoT effectiveness and improvement is the information sharing. The idea of open-standard is the first step in the lever of the lowest cost/highest improvement even if it is in the countertendency with respect to way of thinking of the past decades, in which the knowhow has been preserved internally.

Re-think skills and culture. The old business mindset must be revolutionized. New experiences, new products and new process will emerge and the skills for facing these changes are not yet on the market. Thus, the education and training must drive the introduction of the IoT both in everyday life and in the industrial environment. A balanced mix of creative, analytic, data, technical and business process skills will be critical but a key factor for succeeding competition.

Experiment. The adage “think big, start small” is central in the IoT revolution. Because the employment of pilot and testing plant allow to deeply understand the IoT benefits, risks and solution for avoiding or retain the risks. Run gradually bigger experiments builds stronger capabilities.

Know the risks and rules. Security, privacy and safety are undermined by the IoT and the share of information. Ensuring them to the customers, employees, assets, partners and all other parts of the value chain of the company is fundamental to gain the trust of all them.

Establish your ecosystem. IoT is built up of components connected to each other for delivering values. Define the partners by areas and the relations between them allows a clear identification of the solutions for the IoT system to be implemented.

Chapter 5. CYBER PHYSICAL SYSTEMS

Cyber-physical systems are one of the technology enablers of the industry 4.0 because they comprehend all the elements directly in touch with the physical environment, as well as the final product to be delivered to customers. These components are mainly subdivided into three main categories: sensors, actuators and tags. Obviously, these devices are not introduced for the first time by the cluster industry 4.0. However, due to the dynamic nature of the physical world and requirement of a continuous flow of information, CPSs must adapt their functionality according to the environment they are working with. This data is sent to the central control, through the internet of things (CPS and IoT cannot exist one without the other).

The idea of integrating the last updated communication technologies in the manufacturing plant through the ICT increases the competitiveness and fosters the industry innovation. This integration will be carried out by the implementation of the cyber-physical systems and this process will reinvent the productive processes and make achievable the “smart everywhere” vision. Thus, the development of non-trivial embedded sensor units, network embedded systems and sensor/actuators networks have made possible the increasing complexity of the application fields with the main characteristic of receiving seamlessly large amount of real-time data. Moreover, the CPSs are able to interact with all the hierarchical layers of the automation pyramid and enforce the overall information exchanging, resulting in a better product-service development. At the beginning of the 2017, Europe accounts for the 30% of the world production of embedded systems, specifically in the automotive, aerospace and healthcare sectors.

The term “cyber-physical system” has been used for the first time in 2006 at the National Science Foundation (NSF) in the United States, describing a countless engineered systems multi-disciplinary and physical-aware embedded computing technologies integrated in the physical environment. The program director of the national science foundation, Helen Gill gave a simple and complete definition of the CPSs “cyber-physical systems are physical, biological, and engineered systems whose operations are integrated, monitored, and/or controlled by a computational core. Components are networked at every scale. Computing is deeply embedded into every physical component, possibly even into materials. The computational core is an embedded system, usually demands real-time response, and is most often distributed.”[25]

The first challenges of the providers of the technologies related to the cyber-physical systems are two.

The first regards the business model. The cluster industry 4.0 is not related only to the biggest companies, quite the contrary, the fourth revolution is mainly oriented to the SME. This problem is like a bucket comprehending several challenges: privacy, security, dependability, genitive abilities, human interaction, ubiquity, standardization, robust connectivity and governance. Particularly in manufacturing the CPS technology employs the latest achievement in computing systems for managing the big amount of data coming from the environment (for instance the sensors controlling the tools wearing or the real-time productive capacity) and elaborates the data for the actuators.

The second challenge regards the heterogeneous nature of the environment in which the CPS can be employed, this recall what mentioned at the beginning regarding the dynamism of the environment. Companies need new architectures able to integrate continuously heterogeneous automation software conceived in different domains of the plant, like control, diagnostic, modelling, process rendering and human machine interface. Additionally, to the wide range of information, the different nature of the potential application environment makes difficult to

[25] Marin Ivezic PWC partner – The world of Cyber-Physical Systems and the rising Risk of Cyber-Kinetic Attacks

forecast which kind of noise, failures, malfunctioning, seasonality, periodicity, etc. The system will face.

In the following figure is simplified the controlling system in three main steps, from the physical environment to the computer application.

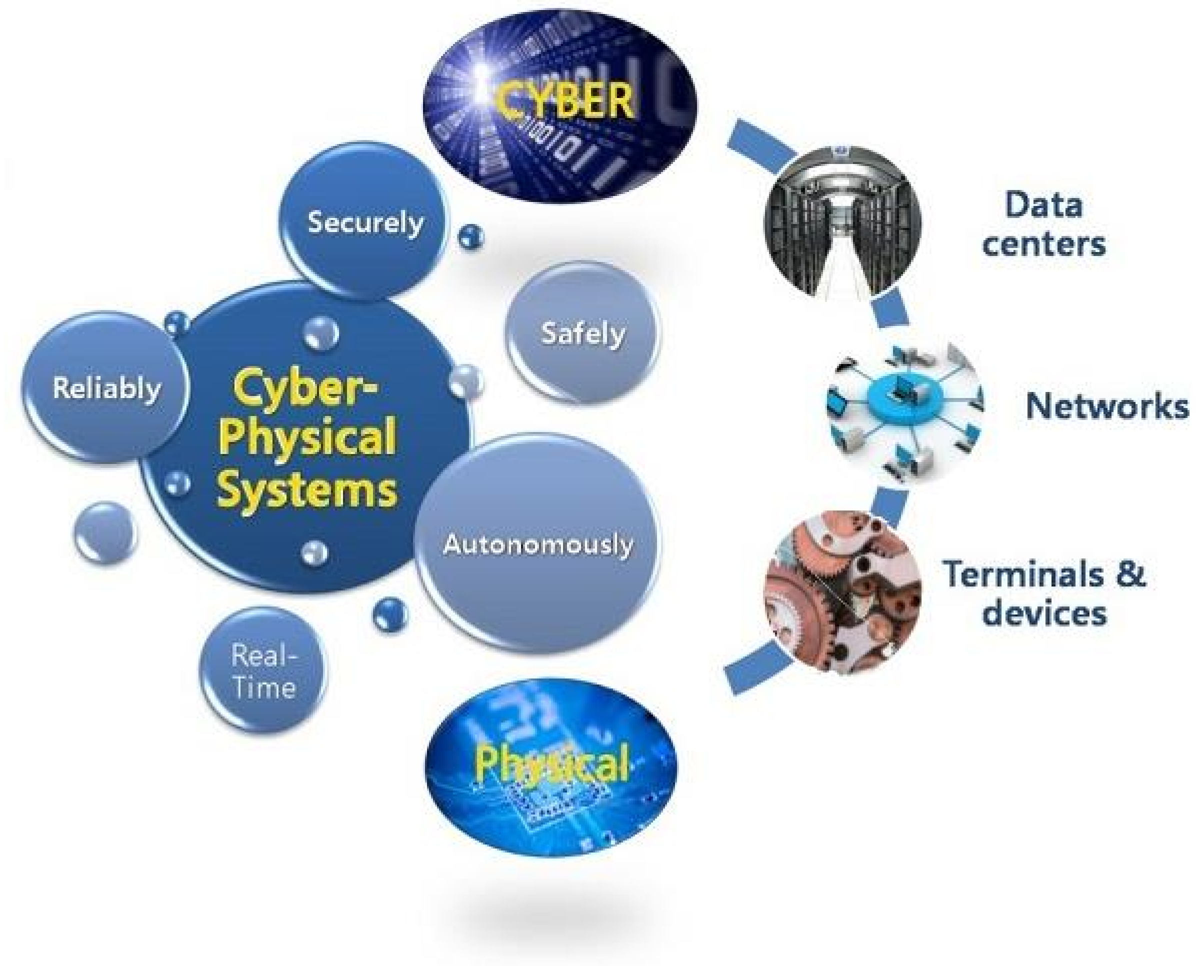


Figure 9. Cyber Physical Systems composition - image modified from CSE 40437/60437 – Social Sensing and Cyber-Physical Systems – Spring 2017

It is simple to understand that the application field is wide, thus as the data can be different and have variability, also the reliability is affected.

The application of the CPS technologies very wide and so the difficulties are not only related to the application field or the difficulties in presenting technologies being up to the requirements, but also to integrate different players and stakeholders. Among these it can be found social and political parts, economic and financial, technological and so on. It emerged that in some cases the difficulties in the penetration of this new technology were not related to technical obstacles or application issues, but they depended by external and contest influences. For this reason, it has been deeply analyzed and subdivided into four factors:

- Cultural, educational and perception. Starting from the education in the school the skills required to the future workers should be acquired through the secondary schools and the universities, these have to involve the next generation into the CPS utilization and managing.

Moreover, CPS technology has the characteristic (as well as the fourth revolution) to be not only linked to manufacturing reality but it is believed to be part of the everyday life of the people, thus the concept to be taken outside the niche of people composing the scientific sector (an example are the self-driving cars, nowadays the enmity is an enormous barrier but, in the future, they should be accepted). Finally, the impact on social and labor issues must be dumped, especially the employment level constitutes the major source of concern at politics and labor union levels. At today, it is not yet clear how smart factories will solve the extinction of some tasks and the creation of others, but it starts to be clear that some of them will be replaced by automated system which in turn will be controlled by a somebody.

- Estimation of costs and ROI models. One of the leading factors for the implementation of the CPS in the smart industries is the reduction of the cost and the optimization of the resources. However, these advantages are only theoretical, the relevance of the digitalization and its impact on the business are not yet clearly identified.
- Law and regulations. The c-level people (top executive level corporate positions, as CEO, FCO, CIO, CTO) and the business & operational managers are oriented to features regarding the legal aspect of the cps, like the liability. For this reason, the legislation will play a central role in the definition of the employment of the technology.
- EU macro-economic factors. The european union is putting at disposal a lot of money, though instruments like funds or tax-reduction. This because the employment of the CPS technology is believed to increase the financial status of all the countries of the eurozone, starting from the increment of the utilization of the GDP and low interest rates.

As the industry 4.0, the “sub-project” of the cyber-physical systems have their own technology enablers. However, differently from the nine defined by the Boston Consulting Group, the technology enablers are four and more generic:

- Hardware/infrastructure. They comprehend all the part ICT of the structure of the system, such as computers, networks and data management systems. These technologies must ensure the capacity of fulfill the requirements for the implementation of the CPS in its application fields. The ICT components need to be seamless and reliable, the high-speed connection is fundamental also in SMEs placed in remote locations, the cost must be affordable. At the level of shop floor, the integration of sensors is fundamental passing from the indoor positioning technologies seamless and reliable, beacon for geo-localization, distribution and interconnection, energy harvesting capacity, embedded wire communication, power sources and single chip IoT system. The infrastructure hosting the system should converge in all the parts of the plant (scalability with cloud, security and modularity), data management technologies able to gather and store large amount of data, additive manufacturing designing technologies, low power and cost requirements, cloud technologies affordable also by SMEs and WIFI & active RFID for extensive geo-localization.
- Software & applications. The platform receiving the data, the solutions and the applications are collected in this category. The characteristics are: handling of complex and large amount of data, data managing security, machine learning, real-time analyzing, robust data analyzation, complex software development (including validation and verification), ensuring the plug-and-play characteristic, processing complex events, cognitive technologies (able to cooperate), virtual and augmented reality, semantic interoperability and cybersecurity.
- Standards. It concerns with standards, regulations, law… Fundamental is the communication of abilities and needs in a universal way utilizing the same protocols and semantics among CPSs. Moreover, the standardization of interfaces simplifies the information sharing among all the components integrated in manufacturing processes.
- Not-ICT. Here are identified all the technologies not directly related to the ICT, these comprise both small simple devices (like RFID and beacon) and more complex tools used for having a physical example of the product (as 3d printing or additive manufacturing). The principal development fields are next generation HMI (Human Machine Interface), robot/gripper

technologies, self-learning and self-configuring, advanced robotics, data ownership (legal support and standards), additive manufacturing technologies.

Application To Machines

It has been already explained that the internet of things applied to the machine to machine communication can provide many advantages, since a network of machine is more valuable than an isolated one and when multiple machines are effectively interconnected, more autonomous and intelligent applications can be generated. A good example of these advantages is the implementation of the real-time control of the productivity, implemented in the productive plants adopting the world class manufacturing, in which screens put on the job shop continuously update in real time the number of finished goods and the number of work-in-progress throughout the line. It is also useful for the accounting departments for legal and fiscal requirements. However, the IoT consists in a central control system based on algorithms able to manage huge amount of data, but it needs devices on machines able to get information and data. Moreover, the CPS comprehends also actuators and tags, as reported in the previews chapters. The combination of sensors, actuators, tags and a central control unit makes the machines able to see, recognize and learn about the work they are performing. For this reason, the current trend in the CPS subject is the self-learning ability of the machines.

In the near future, or even today, the smart manufacturing facilities will be composed of cyber physical systems interconnected all together, improving productivity and quality. Each physical component and machine will have its twin model in the cyber space and each of them can predict, or even prevent, a failure, self-reconfigure and self-optimize for making the process more robust and increase the performances.

The CPS network is built up from different levels, starting from the plug-and-play up to the configuration level, in which the machine is able to perform self-management activities.

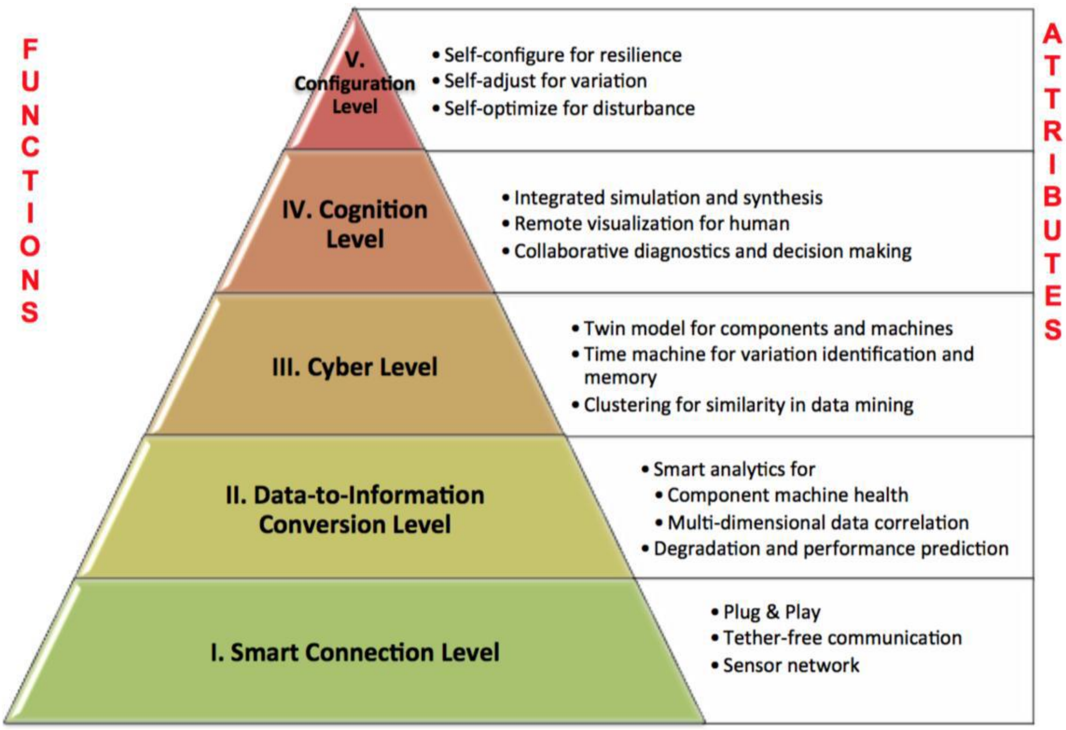


Figure 10. Cyber-physical Systems Architecture for Self-Aware Machines in Industry 4.0 Environment – Wikipedia CPS for manufacturing

1. Smart connection level. This level comprehends possibility that some machines have already today, such as plug-and-play, tether-free communication (architectures based on it are well known, using ZigBee, Bluetooth, wi-fi, UWB, etc.) and sensor network. Compared with the other technologies on the stack, they seem trivial but they are not at all. The first important step in this level, that will be crucial for the development of the entire pyramid is the ability of the machine to be interconnected to a remote control in order to avoid the requirement of an operator (or a computing control) in loco.
2. Data-to-information conversion level. In the manufacturing environment, the sources of information are many (sensors, controllers, maintenance records, the manufacturing system itself and so on). All data must be converted into meaningful information for a real-world application.
3. Cyber level. At this moment, information has been converted in a way that allows the central control unit to have access to them. The next level consists in exploiting these information for impacting on the production system. One of the most widely used utilizations is the comparison of data coming from similar machines, for understanding the system variation and life prediction. This information creates cyber avatars of the physical machines and increases the knowledge base of each system.
4. Cognition level. In this level, the machine starts to employ the information acquired for self-managing and preventive activities. The ability of being aware of the problems that can come out is intrinsic in this stage, also by basing this analysis on the historical data. Prediction algorithms are implemented in this phase for estimating and forecasting in time the failures.
5. Configuration level. The capacity of gathering information and employing them for preventing failures, as well as performing proactive maintenance, allow to increment the utilization of these data by making them available to the managers for taking right decisions based on the maintenance information. Moreover, the machine can manage their workload and manufacturing schedule in order to optimize the utilization.

Maintenance

Maintenance is one of the strongest points for the implementation of the cyber-physical systems in the smart industries. The idea introduced by the new technology consists in moving the maintenance from being reactive to be proactive. This roughly means to anticipate the failures in order to fix the problems before they come out, facing it when it not causes yet problems to the closer components following a knock-on effect. This methodology and the scheduled maintenance allow to increase noticeably the MTTF (mean time to failure), reduce the MTTR (meantime to repair) and, consequently, increase the availability of the machinery.

The possibility of adopting this kind of maintenance is given by the interconnectivity, providing a huge amount of data. Nevertheless, an adaptive, flexible and powerful methodology for data collecting, managing and analyzing is required.

The text of Jay Lee and Behrad Bagheri, “cyber-physical systems in future maintenance”[26] reports two applicational example of cyber physical systems.
The first consists in a CPS based wind turbine health monitoring system. In this kind of system, the efficiency and the availability are the most critical factors for the turbine performances, considering also the exposition to atmospheric agents causing degradation, the high number of moving mechanical parts and the risk of failures. For these reasons, the maintenance is the key success factor for a project like this. The monitoring of the performances of the components has been subdivided into three level: fleet level, turbine level and component level. The supervisory control and data acquisition is employed within a condition monitoring system for obtain the most accurate and complete information about the performances. SCARA at fleet level clusters units into peers sets and determines individual performances. At turbine level, the control recaps all the

[26] Cyber-Physical Systems in Future Maintenance – Jay Lee and Behrad Bagheri

data coming and evaluates individual turbine power generation degradation, analyzing the deviation of the current performance from the power curve characteristic of the turbine given by the theory. Due to the dynamic environment, mentioned before, it is subjected to atmospheric agents wearing the components, a multi-regime method is employed to evaluate the degradation over time. At component level, signal processing tools are selected to analyze data coming from the other two level for diagnosing the various failure models, such as bearing outer race damage, planetary gear-tooth scuffing, shaft damage or imbalance and generation of failures under multiple working regimes. Other extraction methods have been developed for predicting drive train components faults, to analyze vibrations under different working regimes and identify specific failure modes on a large scale offshore turbine drive train.
The second example reported regards the CPS based industrial robot health monitoring. This project consisted in developing a predictive health monitoring solution for a fleet of 30 industrial robots in a manufacturing production line. These robots were handling WIPs in various line speeds and therefore complicated multi-regime cyber-physical-based maintenance approach was conducted. The inputs parameters are torque and speed, these are popular fault detection methods for monitoring health condition of industrial robots, with the difficulty of non-invasive placing of the sensors. Another difficulty has been encountered in the algorithm draft considering the nonlinear relation between the operating speed and the torque. Moreover, the data was subjected to various configuration parameters, such as gear ratio, load ratio, pressure calibration, type of tooling for robot servo-guns and other characteristics of the product handled by the robots. At the final sage, the data gathered by the central control system is put on a cloud server. This cloud maintains all the historical data continuously updated with information from all the assets in the fleet. The outcome of the prognostic and health management algorithms is periodically transformed into graphical rich infographics and presented to the final user, that is the decision-making department, though a web based interface in order to take decisions about the equipment.

Retrofitting

As reported by the business dictionary retrofitting means

"modifying existing equipment or structures with additional or new components or members.".[27]

This technique is widely employed in the science of the CPSs simply because the high cost required for renewing all the industrial equipment. The biggest problems in older machines is the risk of unexpected downtime or delays in production, leading to financial losses. Retrofitting consists of improving the functionality and reliability of the machine, making the whole productive process more robust.

The first step of the retrofitting activity is a key point of the industry 4.0, the interoperability. The interoperability consists in making all the machines able to operate as a whole system, rather than as individual components. The retrofitting is no more than replace the outdated and unreliable part with a new one and install sensors and tags.

Finally, this technique does not need to be costly and the times for update a component are obviously lower than the ones for change the machine, thus the downtime are reduced. The drawbacks are obviously the necessity of continuously checking the lifecycle of the components in order to guarantee a good integration of the newest part and the constraints in implementing sensors and tags. This last one is given by the defined architecture of the machine and lead to a small amount of data in the hand of the strategic decision-making department.

[27] Business Dictionary businessdictionary.com

PLC DCS SCADA

The main evolution in the organization of sensors, controllers and communication inside a company's network consists in the passage from the past, and still current, PLC (programmable logic controller) to the DCS (distributed control system). These are systems able to control the process and send all the information to a process monitoring technology, the SCADA (supervisory control and data acquisition). In the following they are analyzed one-by-one.

PLC

Programmable logic controller is an industrial computer continuously controlling and analyzing the state of the system through the inputs coming from the sensors placed on the machines, or even on the entire system. This computer takes decisions based upon a custom program to manage the outputs to the actuators devices. It has been firstly introduced in 1973 and it growth has made it essential. Moreover, it has been widely employed for its capacity of being modular: the operator can mix and match different types of input and output devices to best suit for its application.

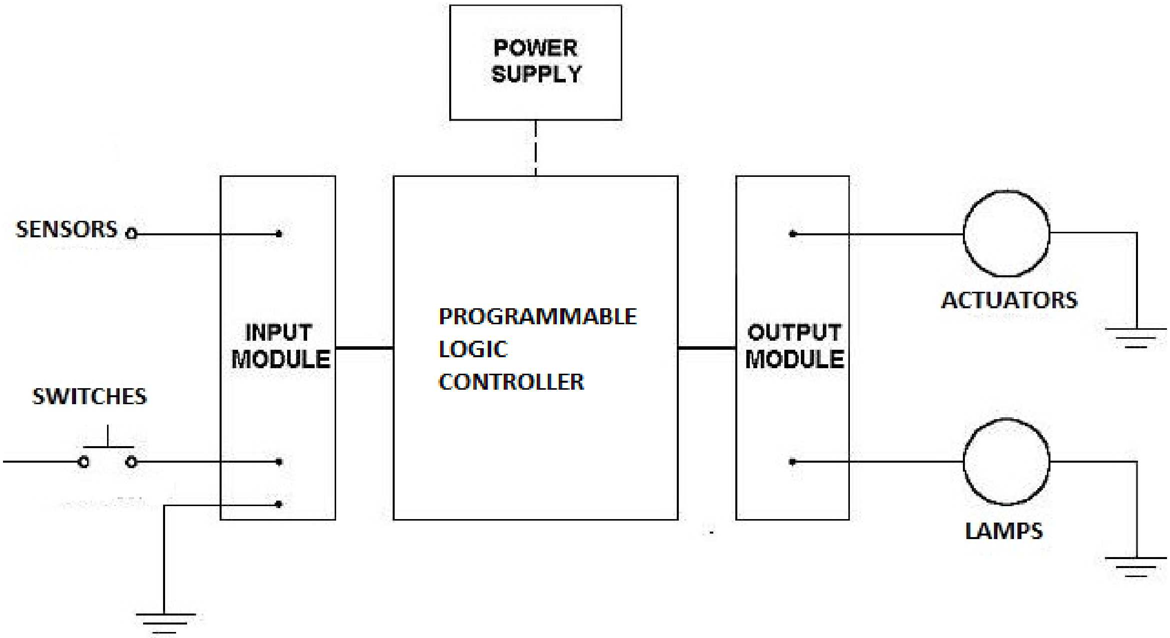


Figure 11. PLC system composition - image modified from Programmable Logic Controller (PLC) – Odesie (myodesie.com)

The central control unit contains the program that manages the PLC and decides how to perform these functions:

- Execute the control instructions contained in the user's programs.
- Communicate with other devices, including I/O devices, programming devices, networks or even other PLCs
- Perform housekeeping activities such as communications, internal diagnostics, etc.

The functional characteristics of a PLC are cyclic, consisting in:

- Input scan: the acquisition of the data coming from sensors, key board, buttons, handwheel, cad drawings, etc.
- Program scan: execute the user created program logic.
- Output scan: activate the output devices connected.
- Housekeeping: the information acquired and elaborated are communicated to the programming terminals, internal diagnostics, etc.

The advantages of the PLC are:

- Since the control is performed by a single processor, all information is easily achievable.
- The simple architecture is simple to be implemented and maintained
- The limited number of hardware components leads to a significant cost reduction.

The drawbacks are:

- There is no physical segregation for physical application, such as protections.
- A single failure of controllers could lead to complete shutdown the control system, thus for some applications a true stand-alone system is required.
- The cost of cabling is a constraint for the dimensions of the system, thus on long distances it is impracticable.

DCS

The distributed control system is based on an opposite idea than the PLC. The design of the system consists in some geographically distributed control elements over the plant, or the control area.
Thus, while the programmable logic controller employs only a single centralized control unit handling all the functions, the DCS uses a more end-to-end controlling having a dedicated controller on each element, machine or fleet of machines. All these local controllers collect and share information among all the plant area via a very high-speed communication network.

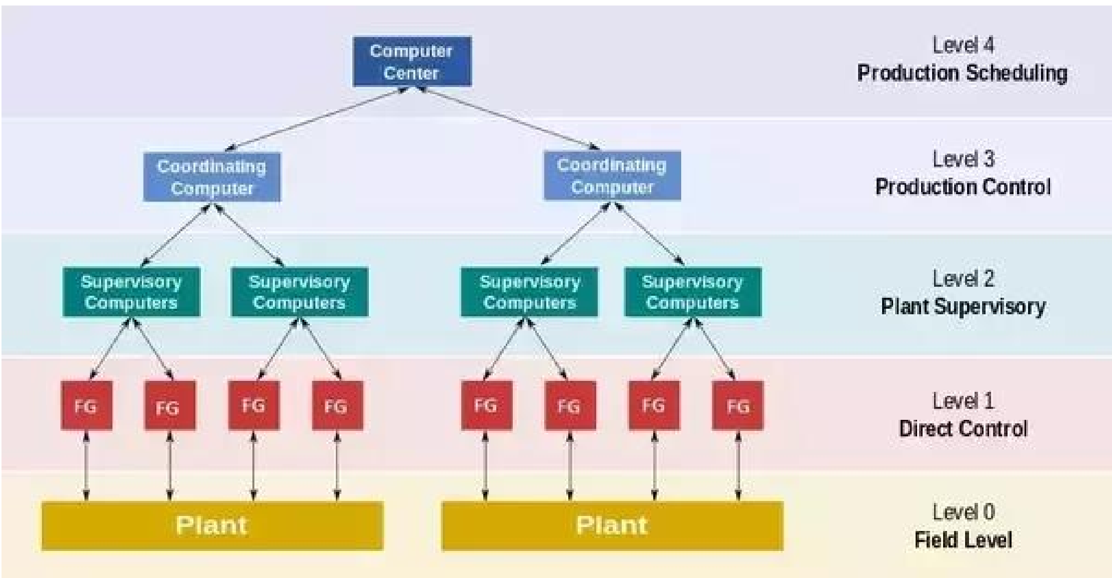


Figure 12. DCS system level composition - image from Big future for cyber-physical manufacturing systems – Behrad Baghieri

DCS controllers are microprocessors based unit distributed functionally and geographically over the plant, ensuring the gather and share of data to another hierarchical level (as the figure above) through different field bus employing different protocols. An example of a network of DCS is shown in the figure below.

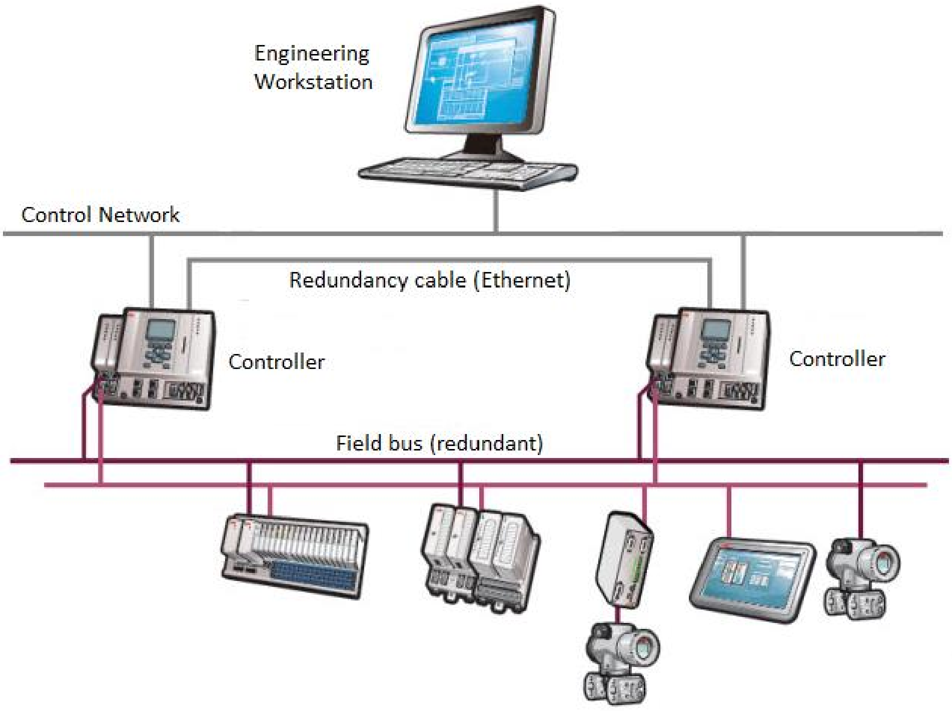


Figure 13. DCS system's elements connections – modifying an image from What is Distributed Control System (DCS)? – Electrical Technology

Due to the cost of utilizing a lot of microprocessors, the cost of this technology is higher than the PLC, thus the most suited application field is the large-scale processing or manufacturing plants. The major advantage of such a system is the standing alone capacity, in fact in case of failure of one controller the rest of the system continues to operate irrespective of failed element, machine or fleet of machines.

The entire architecture of the distributed control system is managed by a so called "engineering workstation" having a supervisory role among the entire system. It can be a simple computer with a dedicated engineering software. This engineering station offers powerful configuration tools allowing the user to create new loops of information, introduce input and output points, modify the sequence of the control logic, configure various distributed devices, prepare the documentation for the information share, etc.

Therefore, the end points of the system have a local control unit (also distributed controller or process station). They are composed of one or more process station that are extended with different types of I/O units and a field bus that is necessary for the communication, for direct or remote connected I/O. The field devices like actuators and sensors are connected to this module, or even directly to the field bus (in this case they are called "smart field devices").

SCADA

Supervisory control and data acquisition is a solution for data acquisition, monitor and control system covering large geographical areas. It combines data acquisition and telemetry. Thanks to their nature, the SCADA systems are mainly employed for implementing the monitoring and control of an equipment or a plant in several industries (telecommunications, power plants, water and waste control, oil and gas refining, etc.). An example of this technology in italy is in the railway application by "Ferrovie dello Stato"[28], in fact, the DOTE (Dirigente Operativo Trazione Elettrica) is comprehensive of all the plants needed to guarantee the quality and continuity in the electric power distribution. The activities of this role are the ordinary and extraordinary maintenance activities on the distribution grid. The control activity is performed by

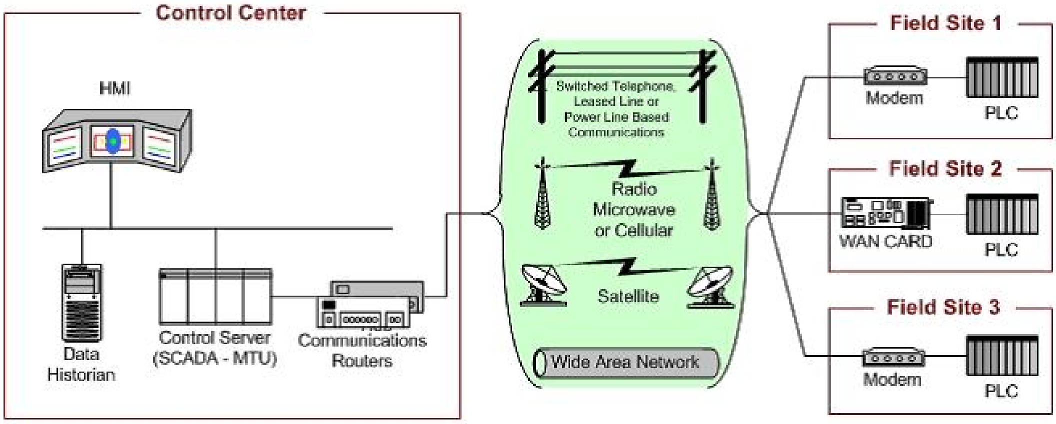


Figure 14. SCADA system general layout (NIST 800-82) - An Introduction to Industrial Control Systems Security Part I: An Overview of Industrial Control Systems – Leron Zinatullin's Blog

SCADA systems, by which the team in charge is able to verify and modify the arrangement of the entire distribution.

The SCADA system control several remote terminal units, performing measurements under field or process level in a plant, and then data is transferred to the SCADA central host computer that process the information. After the treatment, this data is displayed to the operator and the corrective actions required will be sent back to the actuators on the plant.

Typically, the SCADA system is composed of:

- Remote terminal units. They are the system in loco. Until nowadays, they are programmable logic controllers in charge of properly convert the remote station data into digital form for a modem to transmit this information to the central system. However, the growth of the distributed control systems is presenting them as more useful, thus in some application they are replacing the PLC.
- Master terminal units. This is the central host control unit, also called SCADA center. It communicates with several remote terminals units, by performing reading and writing operations during the scanning.
- Communication system. It is the network allowing the information share between the remote and master terminals. The medium can be cable, radio, telephone, satellite, etc. (or combination of these.
- Operator workstations. This is the interface between the operators and the system, it is made of computers terminals of standard HMI software. These workstations request the information to host in order to monitor and control the remote fields' parameters.

[28] Ed.

Employment in the supply chain and logistics management

Increasing the number of actors inside the supply chain and the complexity of the product requested by the customers have resulted in a snowballing complexity of the whole supply chain model. The following scheme represents a standard supply chain model in which we can note how the different actors interact and what are the directions of the physical and information flows.

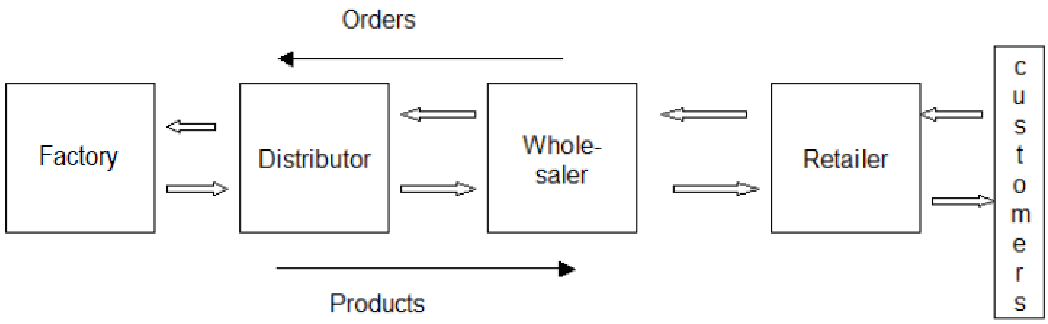


Figure 15. Physical and information flows inside logistic. - Image from the course of Advanced Automotive Logistic

More specifically the factors influencing the complexity are: number of actors, differentiation of the activities of the actors, degree of decision-making autonomy of the actors, location of the actors (giving distribution delay) and demand variability.

The first result of the complexity of the supply chain is the so-called bullwhip effect, firstly noticed in 1961 by Forrester, who describe this effect as the: "amplification of the variability in the demand/order signal that occurs when he move upstream, from the retailer to manufacturer, along a logistics chain (Forrester, 1961). "[29]. In other words, the lack of exact knowledge of the state of the system leads to oscillation following the changes in customer demand by unpredictable amplitude. These fluctuations are amplified by the shop going from the retailer to the wholesaler and from wholesaler to the distributor.

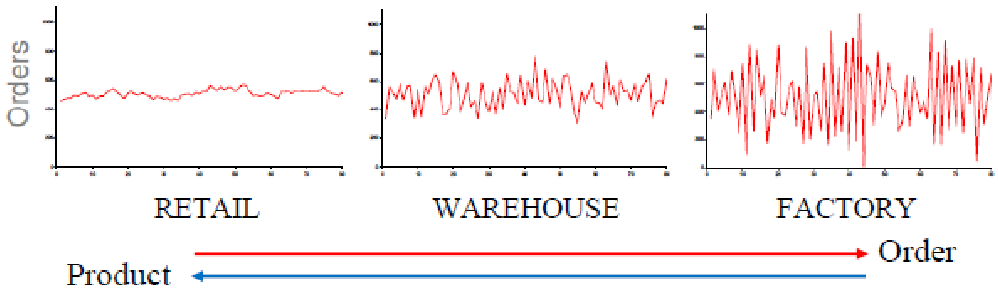


Figure 16. Bullwhip effect. - Image from the course of Advanced Automotive Logistic

The results of this bullwhip effect are: unstable schedule, lack or excess of capacity, lead time increasing, low customer service due to non-availability of products, cost of transport and storage out of control and excessive labor cost (it has been demonstrated that bullwhip effect can impact to the value up to 30% of the cost). This effect at the managerial level results in misperception of market feedbacks and trends for all the parts engaged in the supply chain and consequent measures in the stock policies and panic generation due to unexpected orders.

How do the cyber physical systems can help the stock management and the logistic department? The data collected from the product usage through the CPSs can increase the knowledge that the

[29] Material of the course of advanced automotive logistic – Eugenio Morello – Politecnico di Torino

company has about the market and the customer in order to diversify its products avoiding the risk of misperception of the market feedbacks and trend for all the entities engaged in the supply chain. Moreover, the increase competition requires continuous improvement and the ability to be always innovative and different with new value proposition for consolidating the brand position. To achieve these business targets, the partners must collaborate in creating a shared knowledge of data stored and fusing the information collected along the phases of the product lifecycle (design, plan, produce, delivery, maintenance and service, service disposal or re-cycling), using CPS and IoT technologies.
It is important to outline in this paragraph the importance of the information share between all the actors along the supply chain. In fact, in the near future there will be no more the need of registering and patenting all the information, as well as keeping secret the data inside the company, because of the high number of information sharing that will required when the forth industrial revolution will be well established.

Aftersales

The satisfaction of customers' needs is a common strategic goal for the most successful companies, therefore the marketing department pursues this aspect among all. Creating customer value and satisfaction are the heart of modern marketing thinking and practice, the two objectives are to attract new customers by promising superior values and to keep and grow current customer by delivering satisfaction.
However, until now, the only way to gather information about the customers' requirements and expectation is the voice of customer collection. VOC analysis has a crucial role in the business decision making process within a new product development process, since it aims to understanding the customer viewpoint both in term of perception of existing products and in term of needs and expectations regarding future products. This technique gives the tools for a forecast as detailed as possible in order to avoid the launch of a product on the market with characteristics obsoletes or far from the customer expectations, reducing a lot the business risk. For instance, the techniques used by carmakers are: institutional market surveys (conducted by specialized associations), specific market surveys and surveys conducted by suppliers.

The trend becoming popular nowadays is the employment of social network and mobile devices for detecting customers' sentiments and expectations, thus identifying emerging trends and preferences about both products or services. IoT and CPS technologies installed in the product can offer valuable information on user experience and can be used to detect failures as well as bed usage. This knowledge can be exploited for improving the future products as well as taking them as suggestions for personalizing the products for the new catalogues.
Product specification management solutions can also help the cooperation between the actors along the supply chain, with the development of new agile production lines, thanks to the CPS easy auto-configurable nodes.
Moreover, the customer usage data can be linked with the after-sale and aftermarket parts information to obtain a closed loop feedback about the product (or service). These information to the aftermarket can be interpreted in R&D to understand the middle life cycle product cost, maintenance price, total cost of ownership and how this impact on product attractiveness. Finally, the study and management of the aftermarket data allows the producers to understand the impact of the spare parts life cycle on customer loyalty in using original spare parts, and not equivalent quality ones produced by competitors, or even better, controlling the possibility of illegal low cost spare parts in the black market. This can increase the product and spear warranty, providing new services to the customers, prepare a more detailed risk analysis.

Environmental application of the CPSs

The limited availability of the supplying resources, the necessity of taking care about the environment and the strong position taken by the government in environmental regulation and laws lead to make the companies more aware for their impact on the environment. As result, industrial manufacturing companies are expected to develop solutions in order to face with stricter regulations, considering all the sustainability features to design factories with the lowest impact on the surrounding environment (i.e. Not only energy consumption, but also co2 emissions, pollutants, wastes, scraps, etc.) and put efforts to develop sustainable manufacturing systems. In this scenario, the CPS technology must provide the intelligent capabilities (i.e. Sensing, monitoring, communication, intelligent decision-making, optimization, reconfiguration and actuation) to achieve the efficiency in resource utilization. This can be pursued by bringing information available at all levels inside the company and check the company resources usage in real time, this in order to adjust the utilization continuously. These data should not only be collected during the productive process but also along the entire product lifecycle.

Human central role

The revolution that the industry 4.0 is bringing to the companies has not been taken as a good renewal from all. Some arguments that the employment of all these advanced techniques can replace the human inside the factories. This is a wrong interpretation of the employment of advanced technologies as CPSs, because these technologies will be adopted for collaborating with humans and not replacing them.

The “cobots” are an example, with them, the human has complete control on the robot in order to perform tasks that are ergonomically poor, through sensors and wearable devices combined to offer guidance, intuitive and powerful interaction. Then again, the robot will be aware of the presence and the position of the human to make the workplace safer. Ergonomics, user acceptance, user experience will be adopted in order to improve the social well-being and the satisfaction, while at the same time the manufacturing performances such productivity, flexibility and responsiveness will increase too.

The manufacturing competitiveness and the need to identify and develop new competencies are making the human factor inside the smart factories of strategic importance. As described in the first part of the chapter, the education and the development of modern “knowledge workers” represents one of the strategy to be adopted to address the urgency of “knowledge economy”, having competencies in modern manufacturing tools. Always it regards the importance of the training, the education of workers able to manage the tools of the industry 4.0 must be sustained by the companies because of the importance of providing the tools for creating, developing and managing advanced skills at the level of the company.

To this end, one of the strongest points of the CPS technology is the possibility of creating avatars of the workers in order to interact and create a symbiosis with the automated systems. Moreover, the CPSs create the optimal environment for the workers in which they can trains themselves on the job, being supported to self-learn and self-assess their performances.

Self-learning

In the near future, the manufacturing plants are believed to be populated by machines able to self-adapt to the environment in which they are and the product they are working with. This revolution in the shop floor will radically change the way in which the manufacturing plants work and it has to be supported by embedded cognitive functions with self-learning capacities.

Therefore, a sensing, dynamic and agile shop floor has to be created, with adaptive process automation, control and smarter integration of execution systems based on intelligent maintenance procedures. These IoT-based factories with self-learning and self-optimization systems require the renovation of the organization and a strategy for describing the behavior of the plant. The human machine interface, the m2m and m2product communications are key aspects for this revolution. Moreover, this renovation must be not only oriented in the utilization of new intelligent machines, but also to implement the new technologies in aged machines in order to improve the manufacturing environment in all the plants, and not only in the newest ones.

The self-adaptation of the machines is already currently used in cyber physical technologies, in the table below there is a recap of the major employment clusters of this technology.

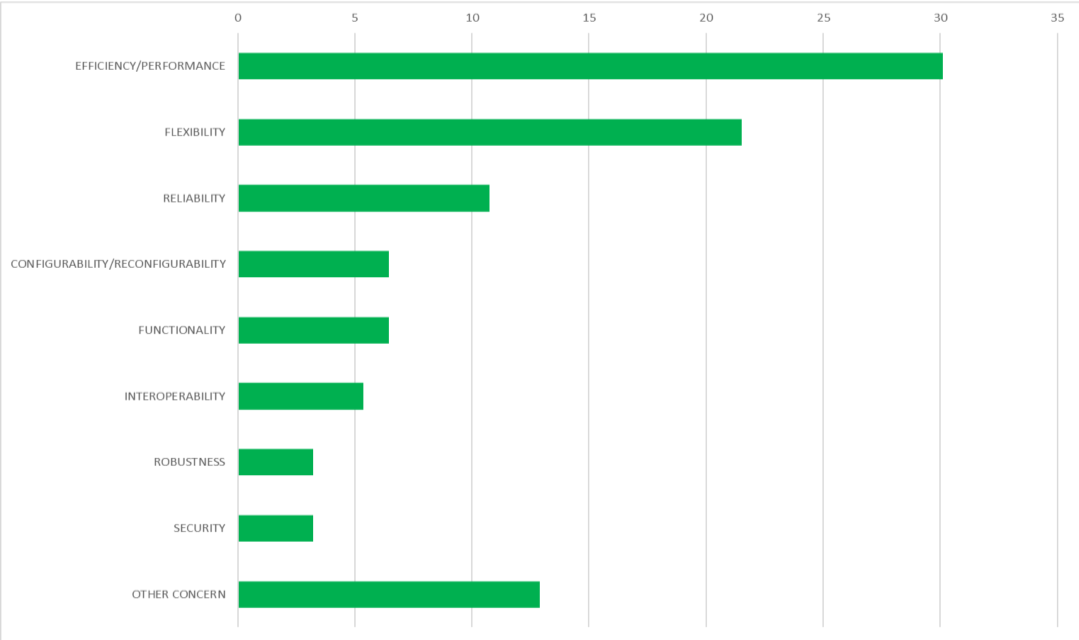


Figure 17. Top concerns related to self-adapting CPS – Self-Adaptation for Cyber-Physical Systems: A Systematic Literature Review – Henry Muccini, Mohammed Sharaf, Danny Weyns

The application domains of this technology are lots and diversified. The chart below tries to show what they are and how much they employ this self-learning technology. General CPS is the adoption independent from a specific domain (data of 2016 by cyberphysicalsystems.org website).

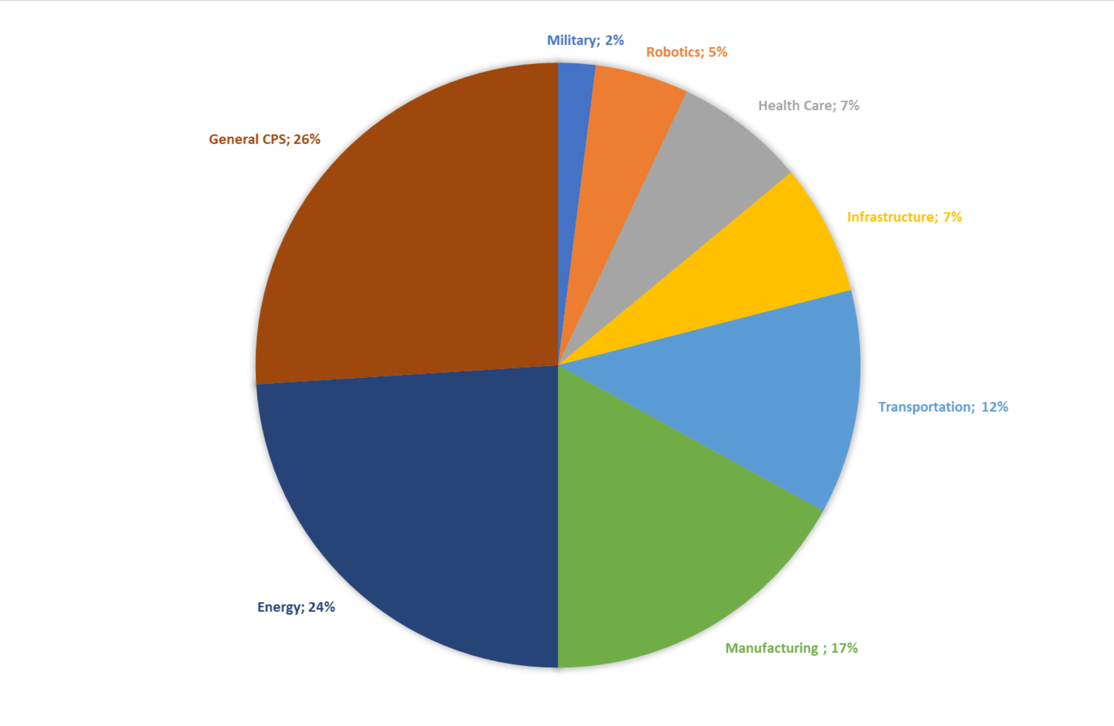


Figure 18. Development fields of self-learning of CPS systems. - image from cyberphysicalsystems.org

Chapter 6. CONCLUSIONS ABOUT INDUSTRY 4.0

Industry 4.0 is a big trend in the nowadays environment especially supported by huge tax relief operated by each single state. The way in which the fourth industrial revolution is changing the way of thinking the product, its idea generation and conception are renewed in order to achieve in the best way the final customer's requirements, at the lowest cost, with the implementation of innovative technologies inside the plants.

Both big companies and SMEs are interested in joining industry 4.0, on one hand, to have the tax reduction. On the other, the risk of remaining backward in a competitive environment like the one they are working today could simply be high as the impact of its consequences.

Moreover, one of the cornerstones of industry 4.0 is the implementation of the internet (inside companies through IoT) and the employment of mobile devices (since nowadays they became fully part of our lives, and this trend is expected to increase). This is an important point for the opportunity of wide spreading the fourth technological revolution to all kind of industries, since the implementation of the internet inside the company is not so expensive, it is enough a telephone line connection and a smart device, as the one we all have in our pockets.

Nevertheless, the internet has incredibly reduced the distances between different places in the world and this leads to higher competitiveness and the improvement of other parts of the company, like the logistic. From the point of view of the author, this has two good effects to the external environment: the first, final prices are lower because of the high number of companies getting closer to the customer with web platforms that decreases distances and the cost of shipping. The second, it is a very good exercise for the R&D because in that way the companies have to plan more and more in advance and thus they invest more during the concept and design of a new product. This kind of competitive situation knocks-out the SMEs, but from what reported in documents from the ministry of economy and industrial development, they will work in order to protect and incentive the small and medium enterprises, to give them the opportunity of enlarging their business.

In Italy, industry 4.0 gained importance and all kinds of manufacturers started to implement this type of technology inside their companies.
However, now the attention is moved to the knowhow. The people in touch with new generation machines have few or no knowledge about the machine and/or the available technology and they need to be trained. “Imprese 4.0” is oriented on this training in order to give, to the person working on this new technology, all the tools to manage their machines inside the line. This underlines the importance of education explained in the chapter 5 about Cyber-Physical Systems.

Finally, this paper is important from the point of view of the author because, until now, it has described the importance of industry 4.0 both from the productivity and social side and for what concerns the ethical and the political environment created by this fourth industrial revolution. From one side, all the countries are trying to collaborate with each other to gain more markets in this or that region, but to the other side, the tax relief every country is improving for the local companies, as light austerity politics.

Chapter 7. TEAM TOOL AND SUSTAINABILITY IN ADDITIVE MANUFACTURING

As the reader can remember from the chapter regarding the enabling technologies about industries 4.0, in between the nine proposed by the Boston Consulting Group, there is the Additive Manufacturing and this chapter is more oriented through that technology.

Rapid prototyping has been the first technology of this category, in the 1980 by a Japanese engineer. Meanwhile, whit a couple of years of delay, Additive Manufacturing has been developed in the eighties by few French engineers, the first technology of this kind developed is the stereolithography. (Gornet, 2014)
After these two AM has grown a lot and nowadays there are 9 different processes for building part with 3D printing: blinder jetting, direct energy deposition, material extrusion, material jetting, powder ped fusion, sheet lamination and VAT photo-polymerization.

AM is gaining importance inside companies mainly for two reasons: the time saving and the cost saving.

TIME SAVING. The advantage brought by AM in terms of time are incredible, since there is practically no retooling time (with some machine this time is quite long only in case of switching the building material). Moreover, the part can be launched in the machine with the CAD file in STL format from the computer, thus the designers have the advantage of immediately having the physical part.

COST SAVING. The AM technology had knocked down the cost for building small amount of parts with respect to the traditional manufacturing machines.

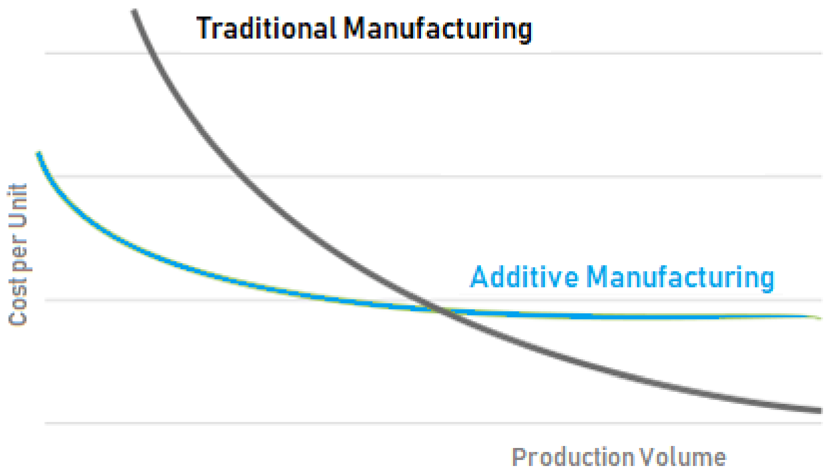


Figure 19. Cost curve for Traditional Manufacturing and AM

However, as shown in the graph above, the cost is higher for the high volume with respect to the traditional manufacturing. The reason why is mainly the impossibility to exploit the economics of scale. Since the AM machines have not been developed for being applied on a production line, thus there is always a down time between two parts produced.

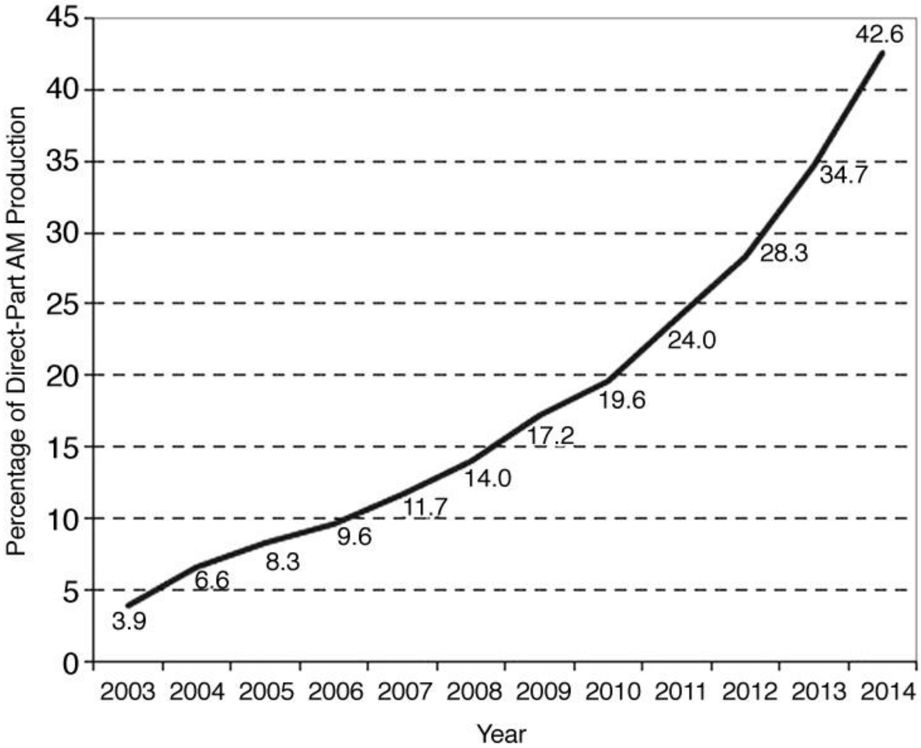


Figure 20. Percentage of Direct-Part produced with AM with respect to years. 3D printer.net

The growing of this technology in the last decade can be easy understood on this graph. Considering the last part, between the 2011 and the 2014 the percentage of direct part produced with AM technologies is doubled up, from more or less the 21% to more than the 42%.

The adoption of this technology is increasing a lot thank to the cost saving possibility for prototyping explained above. However, this increasing utilization is under the rick to be out of control. This can happen because the majority of utilizers are not aware of the impact of their production, both in term of resources utilized and the impact of the product (n term of the material utilized) during the whole life cycle.

WHAT IS TEAM?

For facing this problem, the team I have taken part during my internship has presented the idea of developing a tool helping the user to minimize the impact. The internship I have done has been at the laboratory LCPI (Laboratoire Conception de Produits et Innovation) in ENSAM under the supervision of professors Frederic Segonds and Floriane Laverne. In other words, the tool tries to exploit the concept of eco-design in the additive manufacturing environment.

ECO-DESIGN. A first definition of that is "Eco-design is the development of products by applying environmental criteria aimed at the reduction of the environmental impacts along the stages of the product life cycle." (BAKKER, 1995)[30]. It is a way in which the impact of the product

[30] BAKKER, C. A. (1995). *ENVIRONMENTAL INFORMATION FOR INDUSTRIAL DESIGNERS.* Rotterdam: Conny Bakker.

is no longer taken into account once the product is already on the market, but it aims to move the consideration about the consumptions, impact and recycling during the Early Design Stage. Thus, this way of thinking the product improve the ecological aspects of the production without carrying any reduction in the features required to the product.
More practically, the concept of the tool developed is based on three main points: plan in advance the characteristics required to the prototype, focus the attention of the user on the necessary characteristics of the product (thus avoid building a prototype with features that are not essential for the test) and balance the parameters in input to the machine and the parameters about the CAD file of the part in order to achieve a good compromise in terms of savings.

The tool developed has been called T.E.A.M., the acronym of Tool for Eco Additive Manufacturing. It consists in a simple, fast and intuitive tool provided to designers allowing them to reduce their impact without undermining the characteristics that have to be analyzed from the physical prototype.

The tests for getting the information about the consumptions and the impacts of the production are not finished yet, but a small amount of data has been already collected. The technologies and machines under testing are five. Here below are listed the technology used and the machines under testing.

Technology: MATERIAL EXTRUSION.
Description of the technology: it consists in a nozzle (or an orifice) dispensing material selectively.
Machines used.

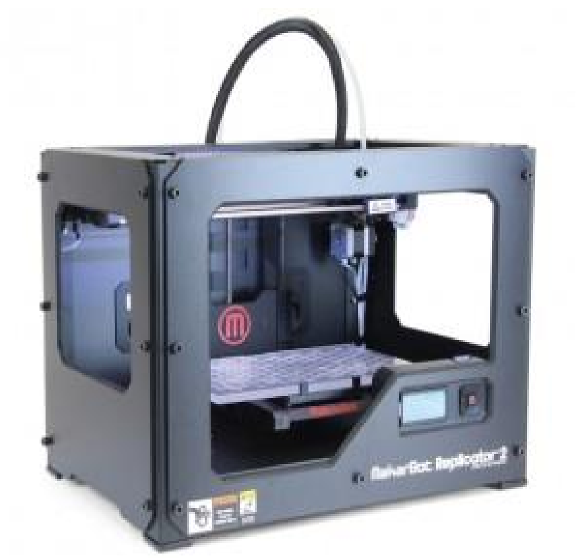


Figure 21.Replicator 2 - producer MakerBot

Figure 22. Dimension ELITE - producer Stratasys

Technology: MATERIAL JETTING
Description of the technology: as the material extrusion the material is selectively deposited, but,

differently from the technology described before, the deposition is made by droplets of material. Machines used.

Figure 23. Object 260 Connex - producer Stratasys

Figure 24. Project 3510 SD - producer 3D Systems

Technology: BLINDER JETTING

Description of the technology: contrary from the other two in this technology the building material is already on the plate and the machine will dispense a liquid bonding agent in order to join the powder layer upon layer.

Machine used.

Figure 25. Project CJP 460 Plus - producer 3D Systems

The project was composed of two parts: the data gathering and the interface.

Inside the developing group I was in charge of thinking, designing and creating the interface of T.E.A.M.

The interface development consisted in presenting T.E.A.M. to the final users in a simple, rapid and intuitive way. For carrying out this objective, it has been decided that T.E.A.M. has to be presented in two different forms: an app and a website. Obviously, since it was the creation part and all the members of the T.E.A.M. were with a production system knowledge, because of the necessity of having people prepared to face problem for what concern productive volumes and product features, the results have been prototypes and not finished apps. Nevertheless, these prototypes will be the starting points for the software developers and IT engineers for creating the final tools in order to launch them on the app stores and web platforms.

The environmental parameters we took into account were: Energy, Material and Flow. The electric energy consumption has been measured by a potentiometer connected in series in-between the machine and the electrical grid. The material employed has been computed by weighing before and after the productive process.

From these, it has been computed also the best compromise of them in order to reduce the environmental impact of our production. Here below I will develop one-by-one all these three parameters and how the Additive Manufacturing machines have impact on them.

Energy. The electric energy consumption is a central point of the AM machines. It can be easily understood why, since the majority of these machine works with laser or other kind of heat sources, the only way to make them work is the electric power. Nevertheless, the electric energy consumed for forming the part, called primary energy, accounts only for a part of the total energy consumed by the machine. The other is the secondary energy. It is the electricity used for "making the machine move", thus that comprehends all the energy for moving the machine's head on the three-dimensional space, the table rotation, etc.

Material. The main problem of the material is that the recyclability of products is quite impossible, especially for the bicomponent products. That is a huge environmental problem. Additionally, the cost of the material is quite high, particularly for some AM machines. Finally, the utilization of two material, the main (composing the part) and the support (precisely for creating the support of the part) made the material impact computation even harder.

Flow. the flow matter is wider than what the reader can think. First of all, the computation took into account the water consumption, the most crucial factor for the analysis of flows. After that the team computed also the utilization of other liquids, like the basic solution able to remove the supporting material I explained above.

All these parameters have been analyzed varying some input parameters not only regarding the CAD part but also other tricks the final user should have to avoid wastes or other kind of useless pollutant.

The interface I was in charge to develop has been subdivided into two different parts. The first one is organized more linearly since it gives the parameters to be implemented in the machine in order to reduce the consumption of one of the three resources described above or the best compromise between them for reducing the impact on the environment. More specifically, this app gives information about:

- the layer resolution
- the interior fill mode
- the support styles
- the scale of the product
- the orientation of the part on the plate
- the production strategy
- the supports removing strategy

First Step App

The decision of developing an app for this kind of prototype comes from the final utilization of this kind of tool. This app is thought to fit people right in front of the machine in order to give them the right parameters at right time, thus a portable device is more indicated for this situation. Moreover, the utilization of portable and wearable devices is one of the nine enabling technologies of the industry 4.0.

Therefore, the first prototypes have been developed one for mobile phone and the other for tablet. Additionally, these prototypes have been developed using two different platforms for software development, here below the are described one by one.

One prototype has been developed with *POP by Marvel*. This software is an open source software available for all the devices, able to simply create basic app. Having a white page, the user can (through click and drop) put images, buttons (from libraries of objects looking like Android or iOS) and text. In another page, it is possible to attribute to any part of every page different links, defining the linked page, the click characteristics (single, double, right/left shift…) and the effect wanted for the page changing. Even at the first impact, this tool seams very easy and user friendly, but, unfortunately, it gives few limited options to the developer. For these two reasons, the first prototype of app has been carried out very quickly and as first impact it has seemed very poor. The attempt of improving the app became time spending and without giving satisfactory results.

Practically at the same time the same app has been developed in *AXURE*. As more professional software if compared with POP, it has been more difficult as first impact, but after it gave more freedom of choice and wider developing environment to the programmer. The first impact is an empty white page, in which the user defines the font (thus the dimensions of the interface). Fortunately, there are a lot of libraries giving imagines and buttons identical to the ones used by the phone makers. Through a side panel, the page interface and the page changing effects can be managed by also defining the links between different screens.

The tool presented in that paper has been developed from white sheet. The importance of that tool is spread throughout all the concept of the industry 4.0 because it is focused on the additive manufacturing, that is very important within this industrial revolution (as said above), and it is oriented through the implementation of hi-tech devices in the modern industries.

The goal of this tool is to enhance the characteristics of the additive manufacturing for what concern the environmental protection. The idea of the developer was to provide to the final user advices that can really minimize the impact of the product on the environment without compromising the characteristics or the properties required for the use. This target is part of the ECO Product Lifecycle Management, it is crucial to make the take an eye on the environment and at the same time not compromise the final product required characteristics. Some enhancing characteristics can be: enclosing voids, reduce the surface finishing quality, increase the strength/flexibility or considering the machine/material cost ration with respect to the final value of the resulting product.

This tool has an important advantage with respect the other tool for the environmental protection, it is developed with the idea of the PLM. That means that its implementation during the development of a new prototype or product starts before the first CAD drawing. Adopting a tool for environmental sustainability during the idea development phase leads to a larger reduction of the impact. Imagine developing a product with considering the environmental effect only during the production phase: this product will already have its own material, shape, production characteristics and, thus, environmental impact.

If designers consider the importance of the environmental impact during the first step of the design, the product can be made up of different material (choosing the most suitable), with the right amount of material (for instance, enclosing voids), with the right productive process (more specifically the less energy spending).

At the beginning it was drawn a flowchart, as the one shown next, explaining the sequence followed by the app.

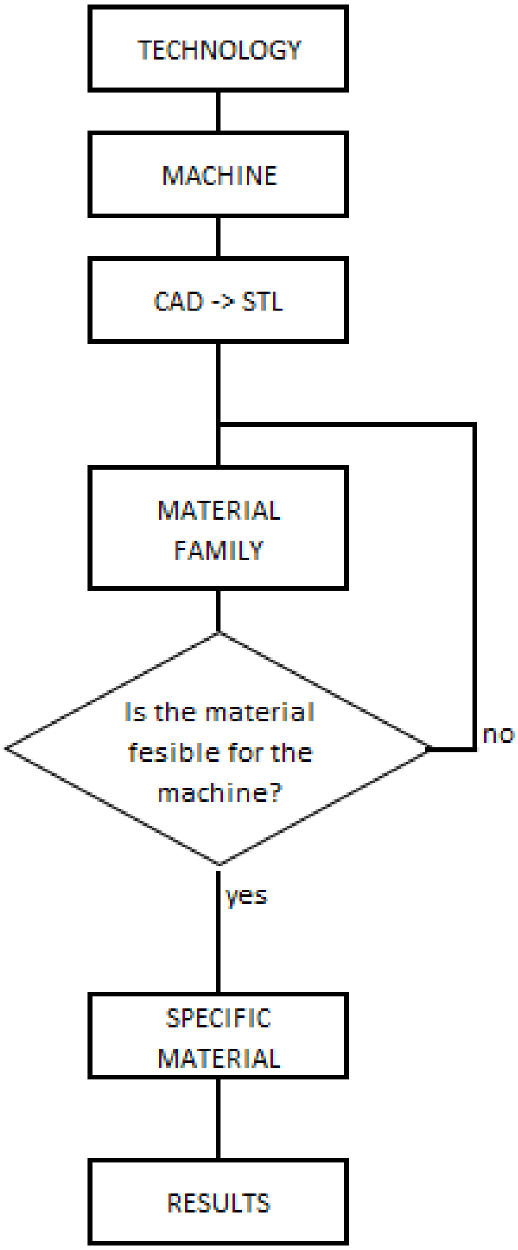


Figure 26. Flowchart of the first step app

The main problem that came out was the difficulties in managing, within the app, the information, given by the user. This because the resulting mobile application of both these two software is able only to achieve one solution, like a story telling, thus the inputs of the user have to converge to only one root. This has been the issue that has driven the optimization of the logic during all the step of the concept definition. In fact, starting from different sequences, the final one is the only one that allows to always only one solution, excluding the machine not coherent with the technology, the material families not coherent with the machine and the specific material not coherent with the material family.

Once the right sequence has been found, the characteristics and the requirements of the app had to be implemented in. Considering the importance of how the questions are presented to the user and trying to make them as more attractable as possible.

In the following figures you can distinguish the two apps developed. The one made with the software POP by Marvel (thought for fitting on android mobile phone, in particular on Sony Xperia) are only few in order to give an idea on how the interface was, while the screens developed with AXURE will be more deeply explained. The second one has been developed taking into account the importance of having a hi-tech device inside the company and, after a brainstorming the team has defined as most suitable a tablet, in particular the template is of an Apple iPad.

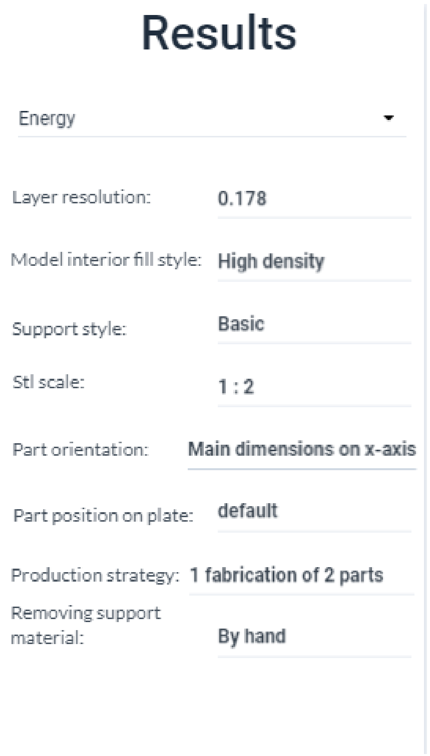


Figure 28. Results screen

Figure 27. CAD uploading screen

Figure 29.Welcome page - APP

The information brought by the welcome page will show to the use what is the tool and which is its goal.

Figure 30. Prototype page - APP

This page is the most important one and is recalled after any decision of the user, because it has the purpose of reminding the choices done in order to have a continuous comparison.

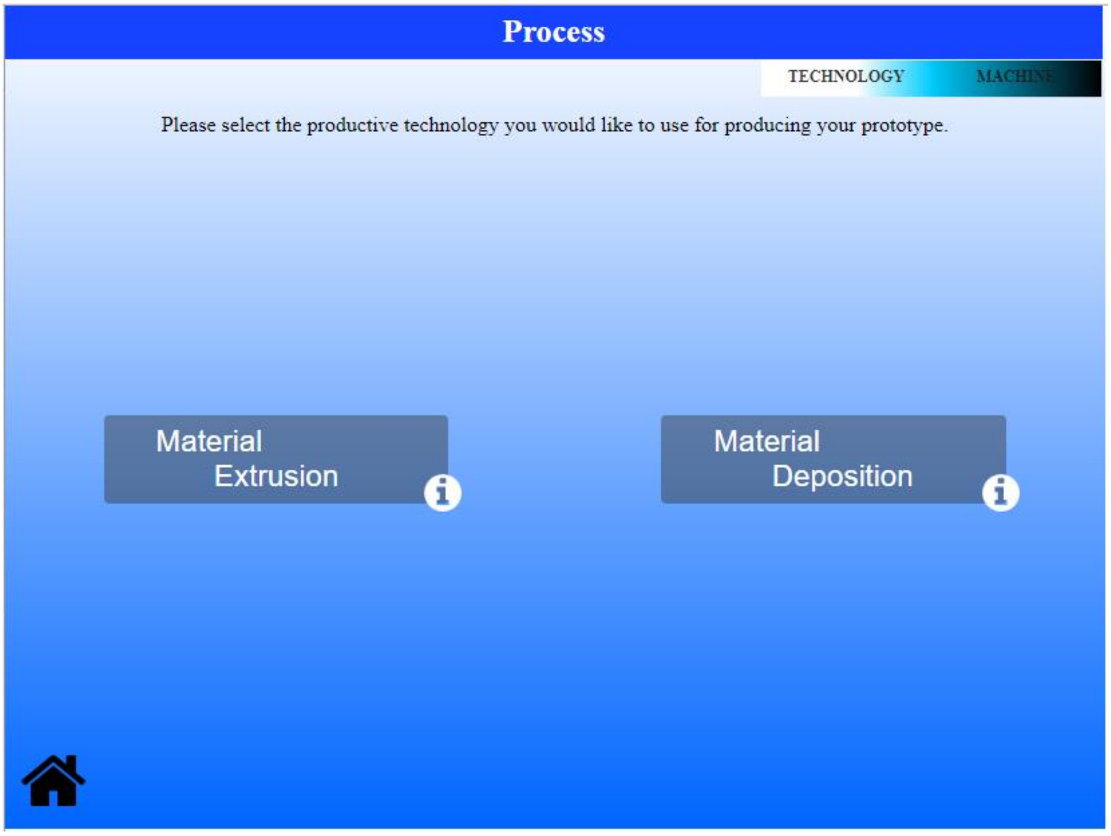


Figure 31. Technology page - APP

Because of the requirement of being convergent, the technology section is important in order to reduce the possibilities for the following steps.
The small "i" mark inside the white point in the low-right corner of the possibilities gives the information about the technology chosen. For defining the choice, the user has the possibility of double click or the check button in the lower-left part of the screen.

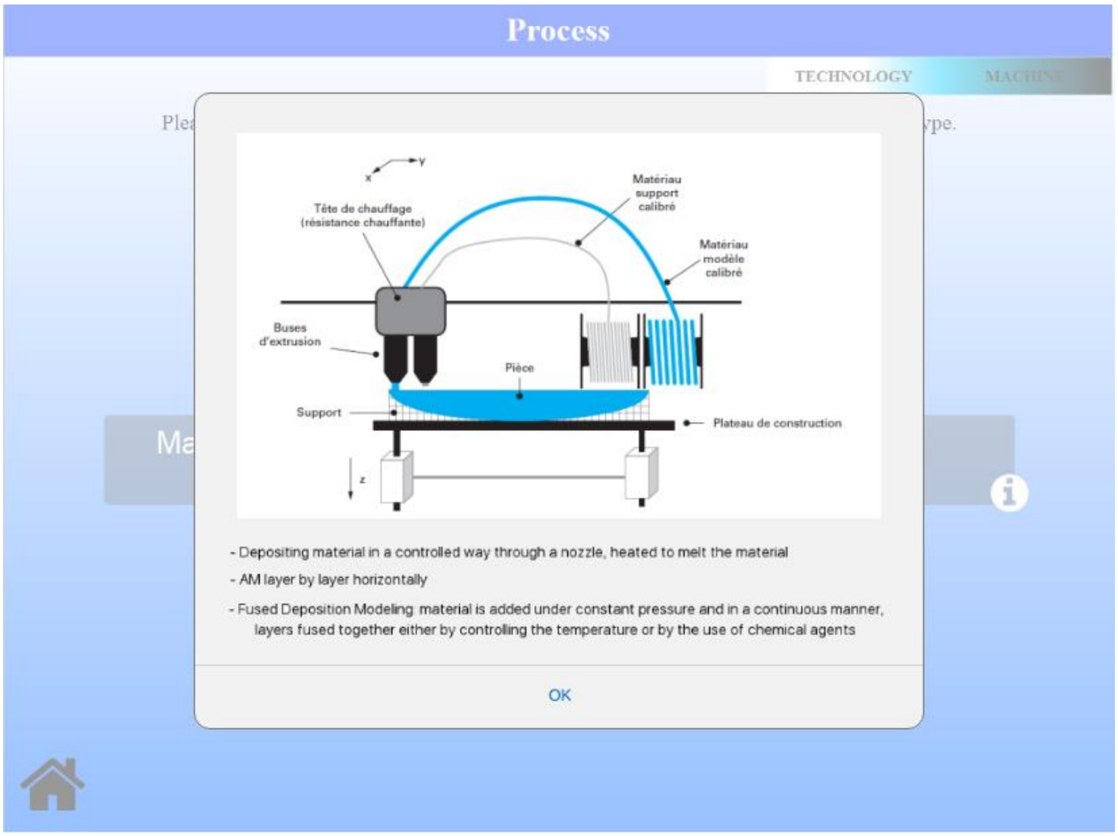


Figure 32. Information page - APP

As a pop up page, the information about the selection (technology, machine or material) gives both an image of the technology and a small description.

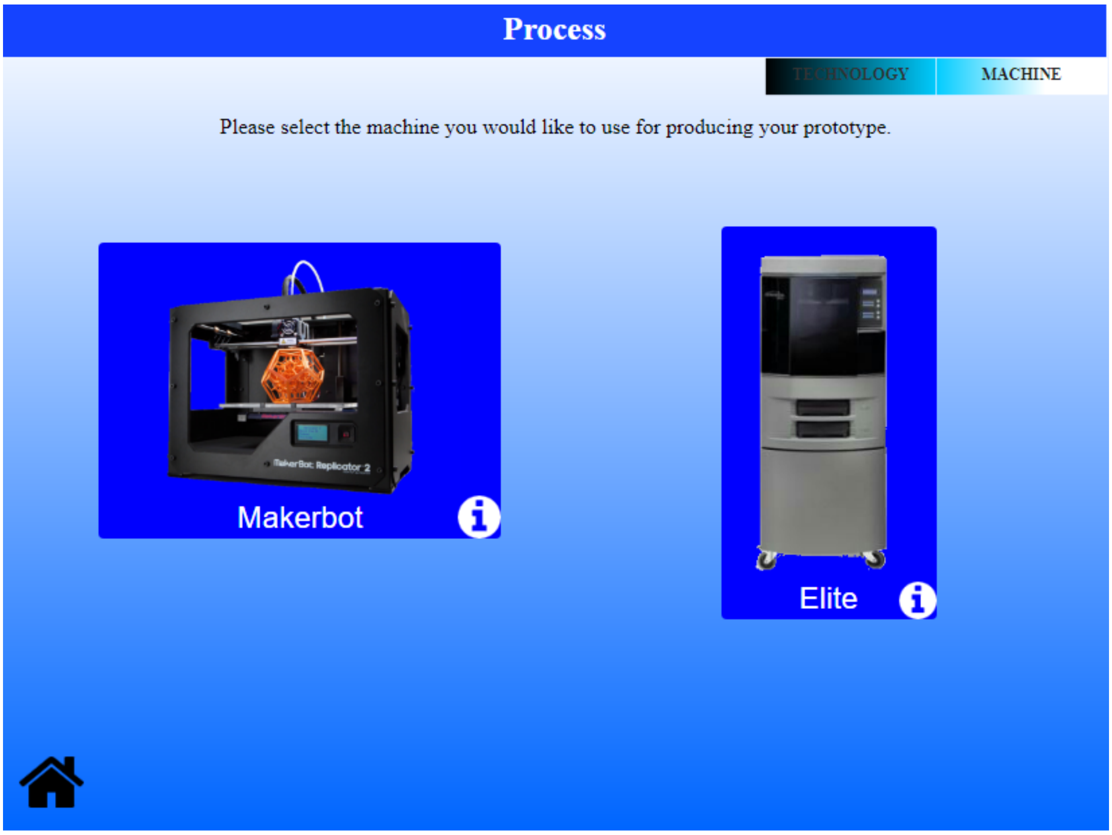


Figure 33. Machine page - APP

Here the page, following the idea of excluding technique, the machine presented in this page are only concerning the technology selected in the preview page.

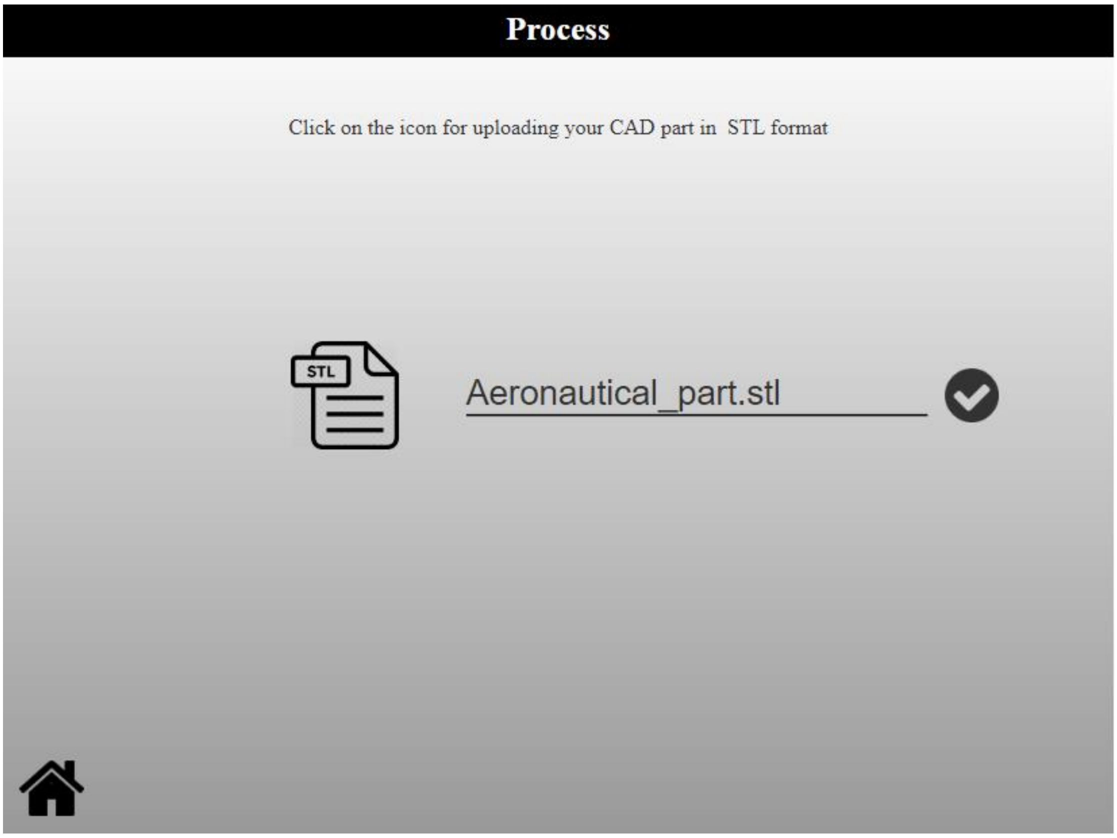


Figure 34. CAD uploading page - APP

The CAD part uploaded in STL file is called by clicking on the icon of the file and, ideally, the browsing inside the documents of the device.

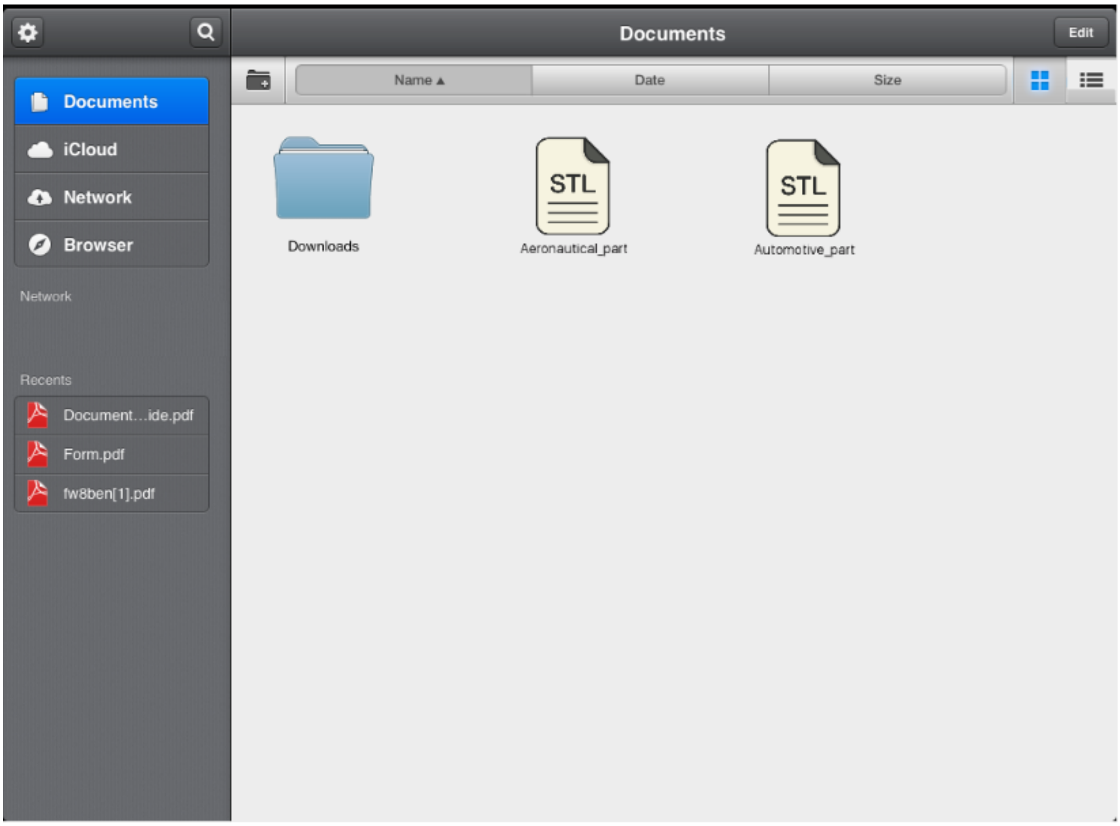


Figure 35. CAD library - APP

For the prototype the document page is simulated. Here is reported the iPod page for giving the feeling of the real app. Once the “aeronautical_part” is uploaded the name is reported and clicking on the arrow aside the name of the file uploaded the file is gotten.

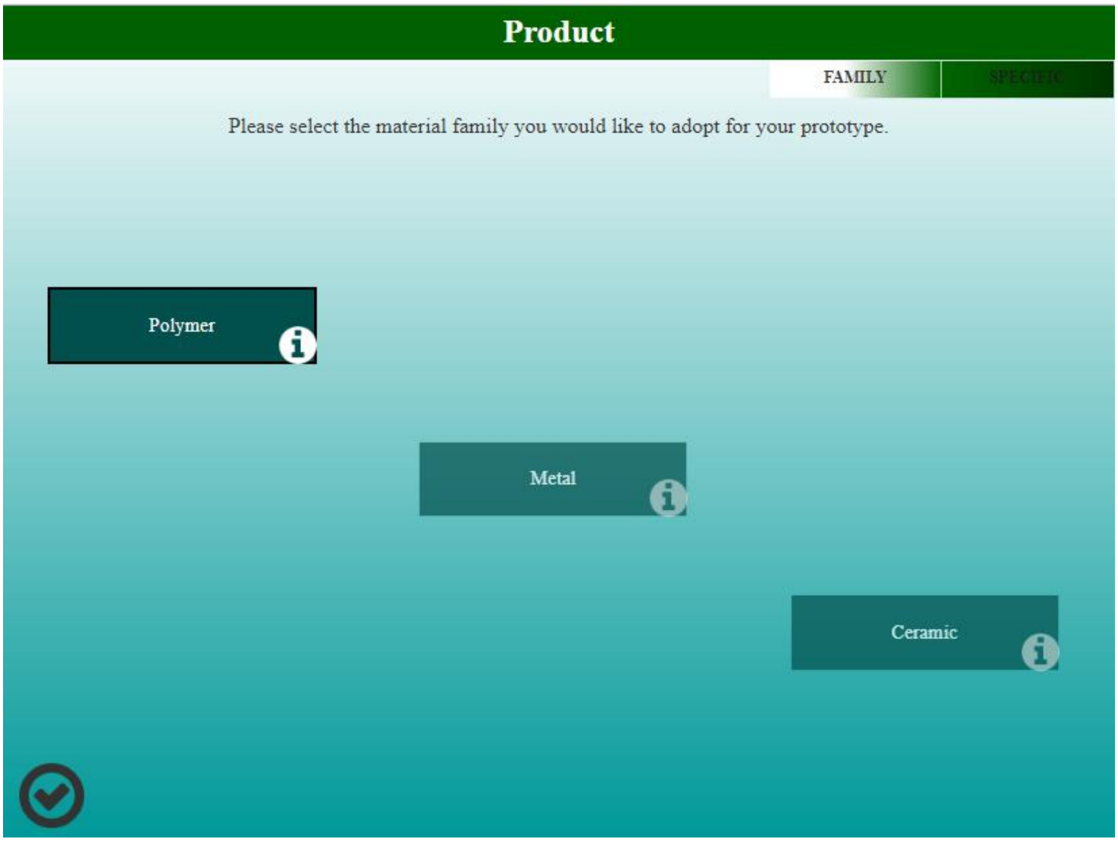


Figure 36. Material family page - APP

As for the technology the material family is presented in order to reduce the number of materials available for the choice of the final user.

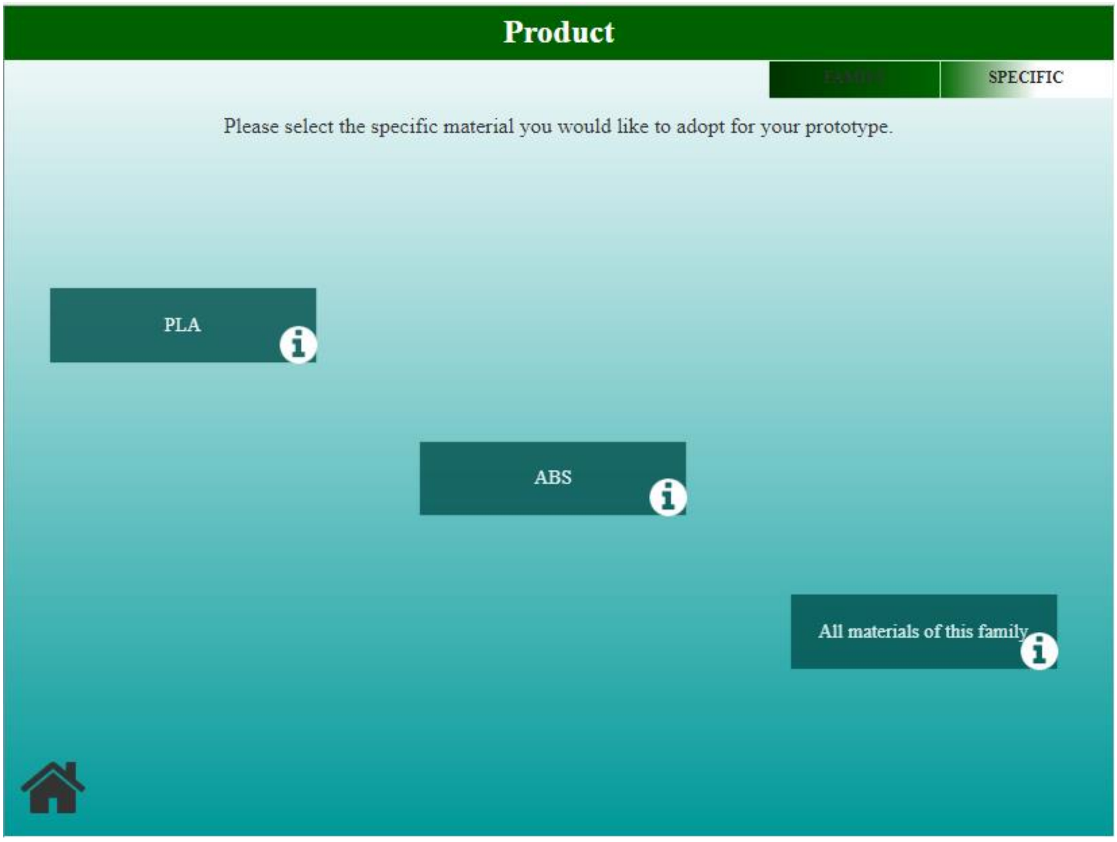


Figure 37. Specific material page - APP

Between the materials only the ones concerning the family chosen are presented.

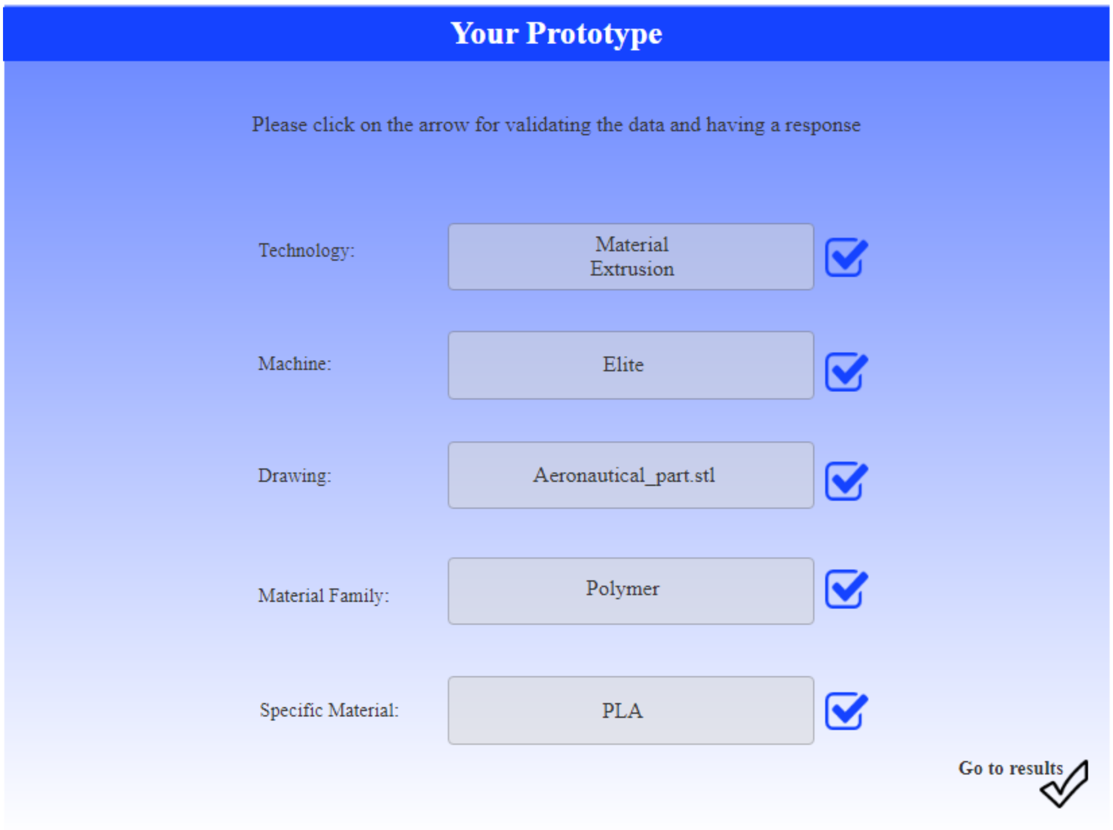
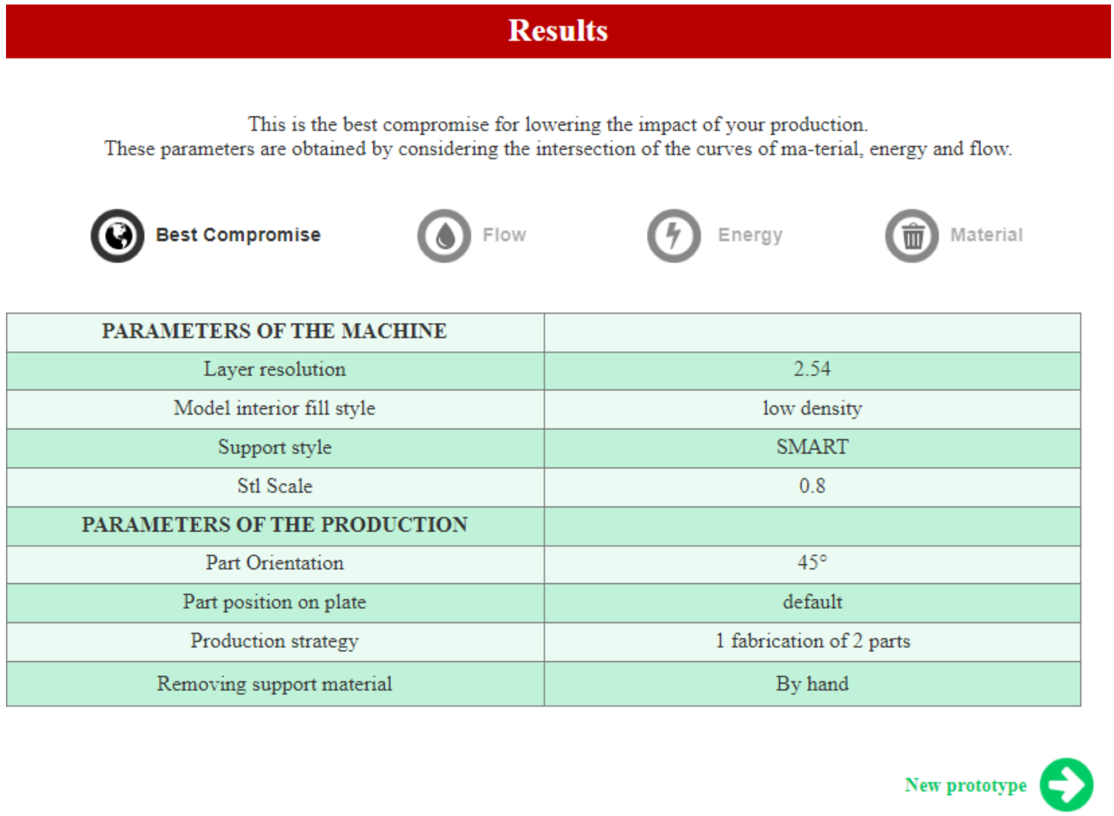


Figure 38. Final recap page - APP

At the end the filled prototype page is this one and the user can navigate to the results with the button in the low right side. The decision of the position is because, as we are used to in the apps already existing, a click on the right side give the idea of leading forward, thus giving additional information.



PARAMETERS OF THE MACHINE	
Layer resolution	2.54
Model interior fill style	low density
Support style	SMART
Stl Scale	0.8
PARAMETERS OF THE PRODUCTION	
Part Orientation	45°
Part position on plate	default
Production strategy	1 fabrication of 2 parts
Removing support material	By hand

Figure 39. Final results - APP

The results are presented subdivided by the kind of resource they aim to save: material, energy, flow and environmental impact. by clicking on the cycles on the top the user can navigate between the four. Moreover, the presentation of the results is made in a way in which they are easier to be read, by filling rows of the table with two interchanging colors. Finally, on the low right-side button the user can return to the initial page and make another prototype.

Characteristics Of The App

As said, one of the main target for developing the app was to make it as more intuitive and not boring as possible.

From the beginning the idea of the rule of three clicks[31] has been followed. It means that in order to define a choice the user should click maximum three times the screen. However, this rule has not been exploited to the letter because the it has been preferred to include a confirmation click (with both check and double click). This because of the utilization environment of this tool, the tablet will be used in the productive plant and can be moved, hanged… thus the probability of involuntary clicks should be avoided.

At the beginning in the app there was an image per each screen but, after brainstorming, it has been decided to make the interface as simple as possible by introducing monochromatic screens. In the same way has been modify the title of the pages and their layout, in order to move the fewest elements possible while navigating.

[31] Boucher, A. (2007). Ergonomie web. Marsat: EYROLLES.

Finally, the browsing between pages has been modified. The navigation in the app in POP is represented by two lines in the bottom of the page reporting the choices, without recalling the main page every time that a decision has been taken. On the contrary, the app in AXURE recalls the page “your prototype” every time the user defines a preference. This decision of implementation has been supported by considering the already existing apps and noticing that the use of the line for showing the preferences defined concerns mainly the web site design.

Once both the apps have been finished and validated, they have been compared. As on the first impression, POP software looked poorer than AXURE. Moreover, since the software in AXURE began a couple of days later than POP, the app was more optimized. For these reasons the AXURE app has been validated as best one and it has been used for performing trials. As last implementation, the output data have been put in the app, dividing them in two sections: the parameters for the machine and the modifications in the CAD part design. Finally, the rows of these tables have been colored two interchanging colors for simplifying the comprehension and streamline the interface.

In order to have a real feedback by final users, the app has been presented to people inside the laboratory LCPI of the ENSAM. Because of the limited possibility of navigation, and thus, the necessity of being guided during the test, it was useless to share this tool on web platforms for testing it. Consequently, the number of trials has been limited, twenty-nine participants have taken part of it, compiling the following survey.

Nous travaillons à développer un outil de conception destiné à diminuer l'impact environnemental lié à l'utilisation de la fabrication additive (FA) lors des phases de conception aussi, nous souhaiterions recueillir votre avis sur certaines fonctionnalités de cet outil.
Nous nous intéressons plus spécifiquement à la partie de l'outil permettant d'améliorer l'efficacité environnementale des utilisateurs de machines de FA, en proposant des paramètres de fabrication adaptés aux besoins mais minimisant les ressources consommées (fluides, énergie et matériaux).

Nous vous remercions de compléter le questionnaire suivant.

MIEUX VOUS CONNAITRE :

1. Etes-vous : ☐ un homme ☐ une femme ?
2. Quel âge avez-vous ? ________________________
3. Quelle est votre formation ?

   ☐ Ingénieur ☐ Ergonome ☐ Designer ☐ Autre (préciser) ____________

4. Etes-vous : ☐ un(e) étudiant(e) ☐ un(e) professionnel(le) ?

   └ Préciser votre ancienneté : ___________

5. Quel est votre niveau de connaissance en fabrication additive ?

   Débutant ... **Expert**

   ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6

6. Quel est votre niveau de connaissance en éco-conception ?

   Débutant ... **Expert**

   ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6

EVALUATION DE L'OUTIL :

7. Que pensez-vous de la saisie des données destinées à obtenir les paramètres de fabrication ?

   Fastidieuse ... **Aisée**

   ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6

   └ Préciser votre réponse : ____
   ____

8. Que pensez-vous des résultats obtenus à l'issue de la saisie de vos données ?

   Incompréhensibles ... **Compréhensibles**

   ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6

   Difficilement utilisables ... **Facilement utilisables**

   ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6

9. Les paramètres préconisés par cet outil vous semblent-ils adaptés aux enjeux de minimisation de la consommation des ressources ?

   ☐ NON ☐ OUI

   └ Préciser votre réponse : ____
   ____

10. Seriez-vous prêt à mettre en œuvre de telles préconisations lors de la fabrication de futurs prototypes ?

    Pas du tout ... **Tout à fait**

    ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6

Figure 40. Survey about the app. Page 1

Notre outil proposera également un atelier vous aidant à adapter la CAO de votre produit de façon à obtenir un prototype qui vous permettra la validation des caractéristiques que vous voulez tester tout en minimisant l'impact environnemental associé à sa fabrication.

11. Que pensez-vous d'une telle aide ?

Inutile		**...**			**Utile**
☐ 1	☐ 2	☐ 3	☐ 4	☐ 5	☐ 6

∟ Préciser votre réponse : ____
____

12. Pensez-vous que de telles préconisations soient contraignantes pour votre travail ?

Pas du tout		**...**			**Tout à fait**
☐ 1	☐ 2	☐ 3	☐ 4	☐ 5	☐ 6

13. Avez-vous des remarques ?

____
____
____

14. J'accepte d'être contacté(e) par mail en cas de questions/éclaircissements sur ce questionnaire

☐ OUI ☐ NON

∟ Mon adresse mail : ____________________________

Merci pour votre participation !

Figure 41. Survey about the app. Page 2

The test with final users gave feedbacks about both the understandability and the importance that common people attribute to the environmental sustainability. For the sake of simplicity and comprehensibility, the surveys have been written in French. They were subdivided into three parts:

- The first was focused on the user, his/her knowledge about the additive manufacturing and its sustainability. In fact, the firsts questions regard the gender, age, knowledge background, if the user is a student or a professor and the knowledge on both additive manufacturing and eco-design.
- The second part was oriented toward the experience of utilization of the app. Analyzing how much the app was intuitive and user-friendly. Here the questions are more focused on the utility of the app: personal idea about the entry parameters, the results achieved (understandability and eventual difficulties), the effectiveness of this tool and the willing to implement this tool in to the future prototyping environment.
- The third, and last, part aimed to analyze the strongpoints of the app and its application field from the point of view of the final user. The last questions are more oriented toward the personal opinion the people have about such a tool in order to make implement these results for developing the following versions of the tool. Finally, there are the section of comments and the possibility to be maintained updated about this project.

The answers were prepared as both open questions and Likert scale choices. The users were asked to fill the Likert scale and, only if they want to, they had the possibility of enriching their feedbacks by using the open questions.

The closed questions have been structured following the Likert scale because of the detailed output and the understandability of this method. It consists in a linear scale (in our case from 1 to 6) in which the first and last points are the two extreme possibilities and the values inside give a balanced response.

There are two main advantages of this kind of scale. First, the analysis gives the results closer to an objective evaluation with respect other feedbacks techniques. The second reason is the symmetry of the choices, the values represented on one side are equally spaced from the other side, thus comparing choices and selecting an entry are more intuitive.

Results Evaluation

Analyzing the opinions given at the first impact, we can call them first impression before filing the survey, the first result that came out is the wide difference of expectations on the app from the users. For instance, the preference of the clicking sequence, some people prefer to double click to define a choice, other want a check button or even prefer that the decision would be taken at the first click. Another point in which the requirements of the users diverge are the button position on the screen. Most of the people are used to have the backward button on the left and the forward on the right, but since the app recalls the same page after every decision the button's position for checking the decision cannot be defined objectively.

From what concern the analysis of the results coming out from the filled surveys are good from the point of view of the interface (second section).

Among a population of 28 users inside the LCPI, with ages comprised between 20 and 35 years old, the results are:

- Usefulness. Mean 4.53 and standard deviation of 0,92.

- Usability. Mean 4,14 and standard deviation of 0,93.
- Acceptability. Mean 4,71 and standard deviation of 0,91.

These results are good because all three are above the mean threshold of 3,5 (the mean of the Likert scale between 1 and 6). For this reason, the output of this test has been good and we have validated the second step app.

Second Step Interface

The second step of this app aims to present a web site form of the tool.

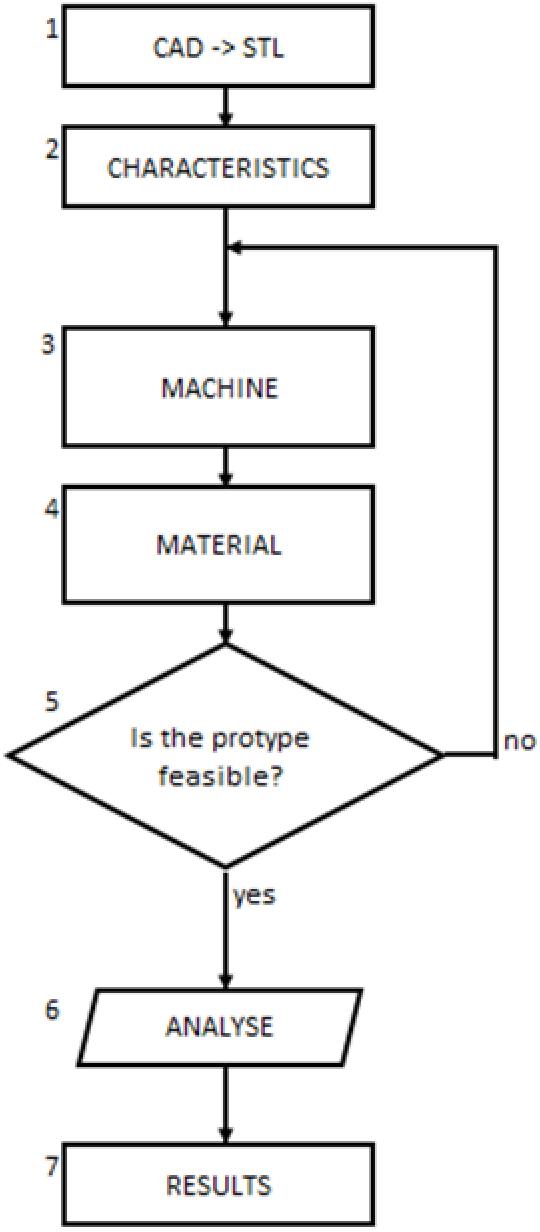


Figure 42. Flowchart of the second step app

As in the first step, the requirements of the first app have been studied developing a main flowchart (shown below, fig. SECOND APP). Moreover, in order to validate the scheme and the layout of the app it has been created a card game to present it to professors.

One of the biggest problem of the second step was the few times at disposal, since the amount of data to be managed and the creation of the code were expected to take much more time with respect to the POP and AXURE models. Moreover, the second interface was expected to treat more data coming from the user.

This second app is more dynamic and gives a more direct support to the final user. As it can be noted from the flowchart in the second step has been implemented the part consisting in suggesting to the final user some advices in order to modify the part for meeting the requirements and at the same time to reduce the environmental impact. Thus, from the user's point of view, the main difference between the two is that in the second he/she will define the final usage of the final prototype.

For the characteristics the team has started from a wide range of alternatives: precise surface finishing, good surface finishing, transparency, filled part, enclosed voids, good internal shape finishing, thickness, strength, inner honey-comb, bi-material (internal/external), allowing air flow, allowing water flow, spring/elastic elements, helicoidal shape, joint, mechanical play (external), mechanical play (internal), projection/protuberance, spring shape, enclosed internal mechanism (clockwork/gear), enclosed internal mechanism (blocking joint) and bearing shape. After, these have been reduced to the four main features:

- aesthetics
- ergonomics
- principle of use
- productive feasibility

At this time another problem come out, the previews flow of alternatives was no longer suitable for this tool, because the importance of the adding the features of the part. Thus, another scheme has been studied and the result was that the interface has to be able to match the input of the user.

It took longer time to start this part because of the need of understanding and learning from blank page. After a week of studies, it has been started to code. As first step, it has been developed the html code, consisting in only the text and images appearing on the screen.

Due to the poor possibilities of only html sources, the CSS code was required. CSS file implements the layout of the screens, for example: buttons, links between pages, checking lists and moving screens.

Moreover, due to the requirements of matching the result coming from the final user interface the PHP code had to be implemented. For this reason, a professor of the LCPI department, who knows very detailed the web language gives the directives on how to program in PHP and a software able to simulate a web server in order to have a trial of how the site works with the database of information and the checkboxes presented to the user.

Unfortunately, due to the few times at disposal, the development of this app had to be fast and so it had only few databases and information matching.

Nevertheless, the implementation of this kind of solution with database give to the website the huge advantage of being improved. In fact, the utilization of database allows an updating practically endlessly, thus the data gathering still working will be easily included in them.

Additionally, for the reason of giving to the user as much freedom of choice as possible, the web site is developed in a way that the use can follow the main flow, thus decide: part characteristics, material and machine, but at the same time, on the navigation tab on the top there is the possibility to move from one page to the other without constrains.

Here below there are the screens showing the website itself with a small description per each one.

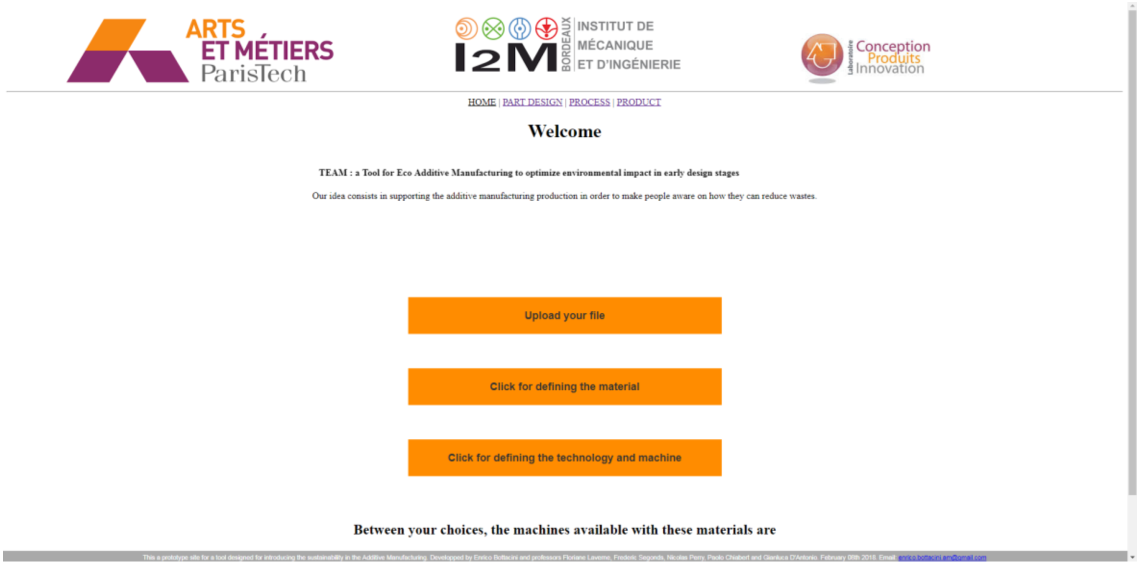


Figure 43. Welcome page - Website

This is the first page of the app, as can be seen it is very simple but at the same time it gives all the information necessary to comprehending the information that has to be implemented. The suggested flow is outlined by the three buttons vertically disposed, starting from the part uploading, since it is the first point that has to be considered for deciding which machines are feasible for the prototype production (internal dimensions and geometry of the machine).

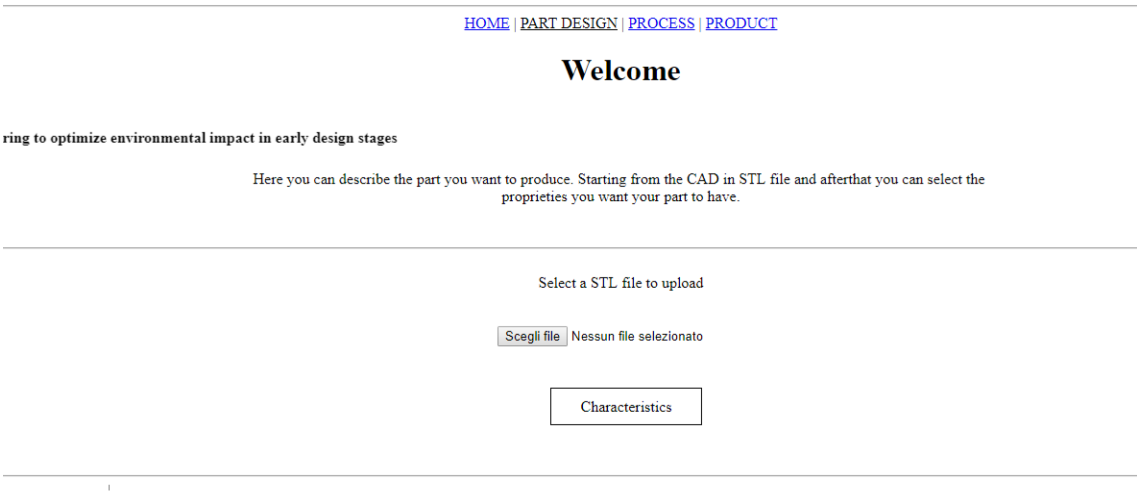


Figure 44. CAD uploading and characteristics - Website

Once the user has uploaded the file in the STL format the final app is supposed to analyze the file and get information about geometry and main dimension of the part. After that the interface will ideally draw a box that will have to be smaller than the main internal dimensions of the machines the user is going to choose.

After the STL uploading the user will be in front to the characteristics. This choice regards the final use of the produced prototype. At the moment there are few of them but with the tests that are still on study the database will grow.

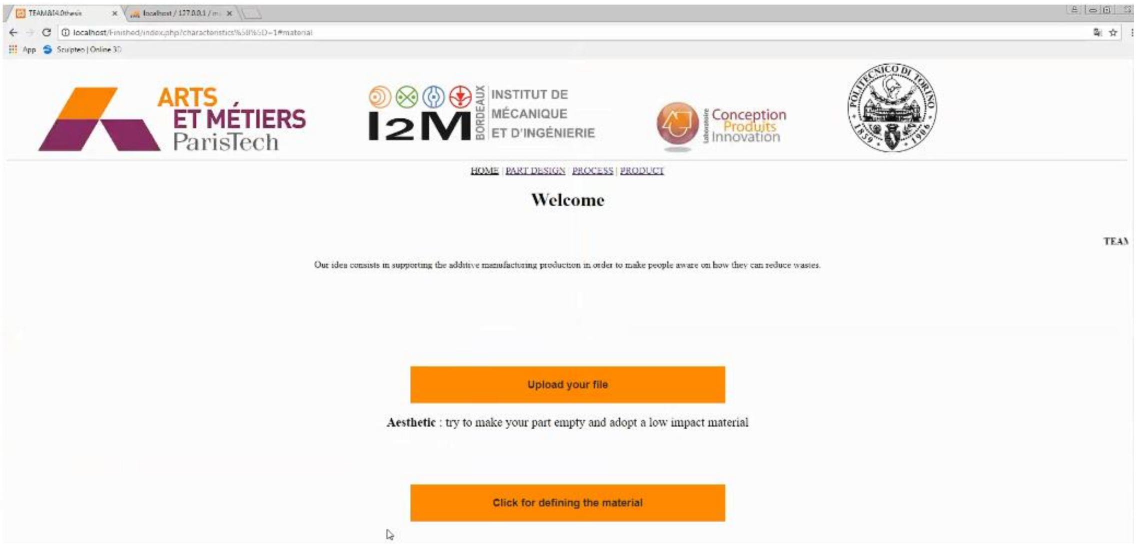


Figure 45. Answer from the characteristic - Website

Once the submission button is clicked the user will return to initial page but here there will be reported the advice about the CAD modification, in order to help the improvement of the design and reupload the file.

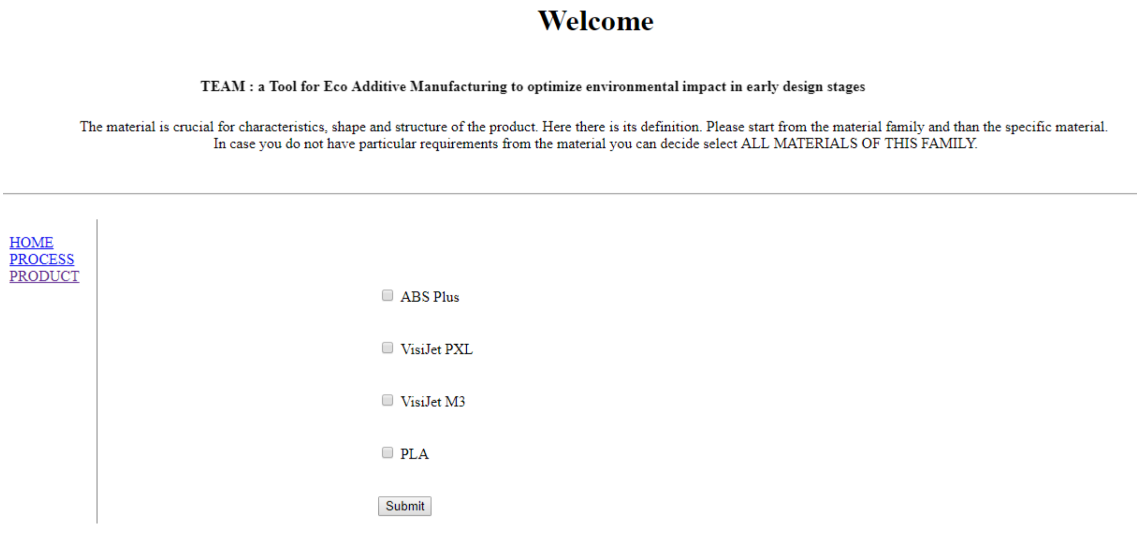


Figure 46. Material page - Website

Differently from the apps here the materials can be chosen independently from the material family, this because of the freedom of choices proposed and the advantages brought by the utilization of a more complex language like html. More than one material can be selected.

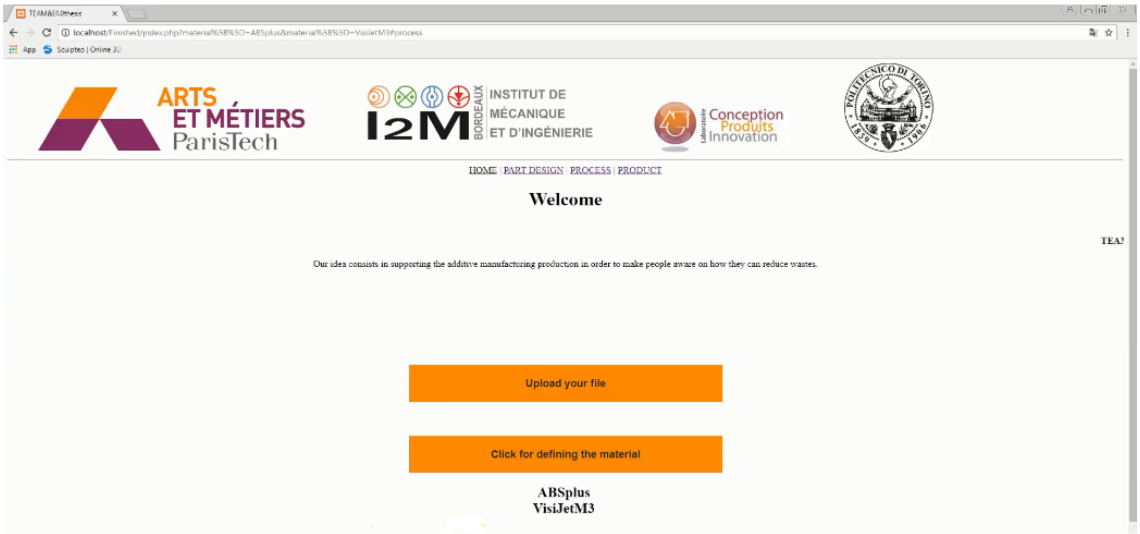


Figure 47. Answer from the materials - Website

Once the submission button is clicked the user will return to initial page but here there will be reported the material chosen in order to be confirmed by the user. For not being annoying the confirm by the user is moving to the next step, otherwise, if he/she will click again on the material button, the decisions taken before will be discharged.

Figure 48. Machines page - Website

As for the material, the machines' choice is independent from the technology differently from the apps for mobile devices. Here the images of the machines are reported in order to simplify the comprehension. Again, the user has the freedom of choosing more than one machine and the site will match the information.

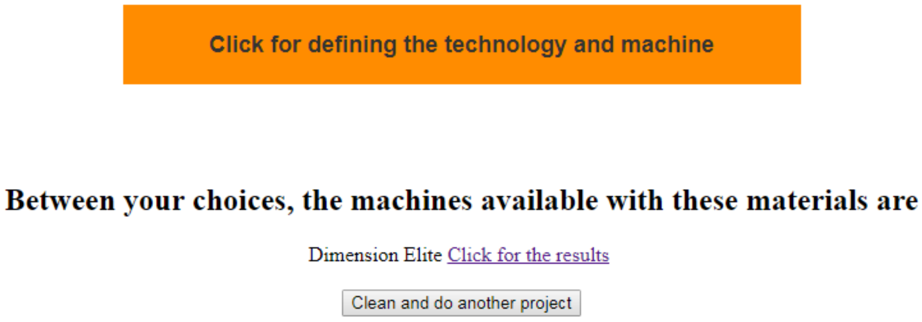


Figure 49. Final output - Website

As for the other the submission button will recall the welcome page and at the bottom of the page the different machines available with the materials are presented. Moreover, aside there is the link to the page indicating the parameters for reducing the consumptions in term of material, energy and flow and how to balance these three resources for reducing the total environmental impact.

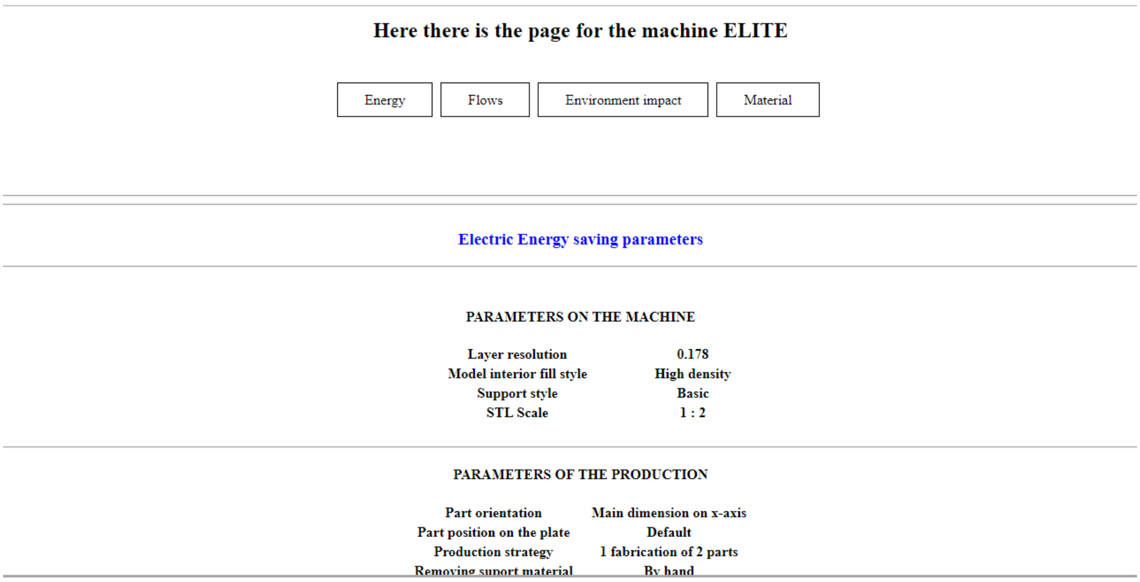


Figure 50. Impact results - Website

Here the three buttons are recalling the parameters of resources saving and the one for the environmental balance. Scrolling the page, the parameters are reported, subdividing them in sections as for the first step tool.

Chapter 8. CONCLUSIONS

During my internship in ENSAM I have developed knowledge about more aspects of industry 4.0: software development for mobile devices and website, additive manufacturing and product lifecycle management.

From my point of view, the bases I have acquired about software development are important in order to be integrated with the production engineering knowledge I have got from my studies. This because the implementation of IT is a key strategy for exploiting the potential of Industry 4.0.

Concurrently, the product lifecycle management (PLM) has focused my attention on the sustainability of the resource utilization inside the manufacturing plants. Moreover, the concept of PLM is strictly linked to the eco-design and the pre-design stages.
These subjects recall the concept of improving the awareness of companies about the impact they have on the surrounding and global environment. The concept of resource and environmental savings are mentioned almost every day both by the mass media (newspapers, newscasts, no-profit organizations and public agencies through sensitization campaign) and governments' global meetings (Kyoto protocol, COP 21, etc.).

Summarizing, this T.E.A.M. is a support for designers. It consists in both an app and a website for a fast evaluation of the production impact of a product, based on the characteristics of both production and part features. This tool is in the right place at the right time. The right place because it utilizes website and mobile devices that is perfectly in line with the I4.0 methodology, not only for the implementation of the smart devices in the companies, but also for the faster and easier gathering of information mobile devices given to users.
About the right time, since the AM technologies are in the first stages of their introduction inside the manufacturing plants, a constant improvement of this tool during the rising adoption of the technology inside the plants could make the tool extremely efficient.

For what concern the utilization of this tool, the employers are more incentive to adopt T.E.A.M. not only because of the consumptions restriction requirements from governments and global organizations, but also because the reduction in material utilization (that is one of the four resources consumption reduced) is translated in money saving, especially for some type of machines.

Finally, my thesis has been developed concurrently with an article that will be presented at the PLM conference that will be held in Torino at the beginning of July. This conference focuses on the Product Lifecycle Management, thus the impact a product has from the concept development to its end of life and recycling (or transformation) and it is held yearly in worldwide locations. The name of this article is "TEAM: a Tool for Eco Additive Manufacturing to optimize environmental impact in early design stages" and it shows the importance of the tool and presents the first step of T.E.A.M., the two apps for mobile devices.

LIST OF FIGURES

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ANNEX

Experience in ENSAM

I have spent two months in a development team in École Nationale Supérieure d'Arts et Métiers. I have worked with T.E.A.M., a group of students and professors that were developing a tool for improving the sustainability of the Additive Manufacturing. We have worked on five machines of the AM technology: Dimension Elite, Object 260 Connex, Project CJP 460 Plus, Project 3510 SD et Replicator 2.

I started my thesis in Italy in October 2017 and I went to Paris on the sixth of January. I started my job on the ninth of January with the professor Floriane Laverne and professor Frederic Segonds.

During the first day I met my professors with professor Nicola Perry too, in order to understand the target of the project I was working on. We had defined that the tool should help the designers in the first stages of the development of a new product.

During this meeting we defined that the tool must not work only on portable devices. To achieve that we have defined that the first prototype should be an app for mobile devices (as smartphone and tablet), while the second is a website for its utilization with a computer.

I attended also a course of professor Nicola Perry to have a personal opinion about the eco-design and planning in advance. Moreover, during this course I learned CES, a software having all the parameters for analyzing the impact of the product on the environment during its entire lifecycle.

At the first stages of app development, I created a cards game for the app and the website, for demonstrating them the operating logic, and after I started to develop the three software.

On the seventh of March I presented my work to professors Floriane Laverne, Frederic Segonds and Gianluca D'Antonio (one of the two professors supervising me for my thesis writing in Italy, with the professor Paolo Chiabert). Finally, on the eighth of March I presented again my job at "La revue des thèses" in front of the LCPI department of ENSAM. My internship finished the ninth of march

Professors Laverne, Segonds and me are going to present the work on the T.EA.M. tool at the PLM conference in Torino at the beginning of July 2018.