POLITECNICO DI TORINO

Corso di Laurea Magistrale in Ingegneria Gestionale

Tesi di Laurea Magistrale

The Digital Twin technology in the Industry 4.0 context

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Ringraziamenti

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Glossary:

DT	Digital Twin
DTS	Digital Twin Shop-floor
DTs	Digital Twin subsystem
CPS	Cyber-Physical System
MCPS	Manufacturing Cyber-Physical System
CPPS	Cyber-Physical Production System
ICT	Information and Communication Technologies
IoS	Internet-of-Services
IoT	Internet-of-Things
PLM	Product Lifecycle Management
PLC	Product Life Cycle
RFID	Radio Frequency Identification
CAD	Computer-Aided Design
QFD	Quality Function Deployment
DIH	Digital Innovation Hub
MES	Manufacturing Execution System
ERP	Enterprise Resource Planning
SC	Supply chain
SME	Small and Medium Enterprises
IIoT	Industrial Internet of Things
CMfg	Cloud Manufacturing
SaaS	Software as a Service
PaaS	Platform as a Service
IaaS	Infrastructure as a Service
CaaS	Container as a Service
AI	Artificial Intelligence
ML	Machine Learning
VR	Virtual Reality
AR	Augmented Reality
AM	Additive Manufacturing
CRM	Customer Relationship Management

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Abstract

The thesis object concerns the study of a new technological paradigm, with deep influence over the industrial manufacturing sector, the Digital Twin. In particular will be put under analysis the impact which the latter have with regards to the SME (Small and Medium Enterprises).

The evolution of the concept of Industry 4.0 has led to the born of new technologies able to re-design the traditional processes and approaches to the firm management. For such a reason, it is offered a broad investigation of literature about Industry 4.0 by pointing out to the Digital Twin.

To support the analysis, it has been conducted a market research, during the internship at Istituto Mario Boella, with the aim to acquire an insight with respect to actual state of knowledge and adoption of the proposed technological paradigm, through the constitution of an ad-hoc questionnaire. Thereafter, the survey has been proposed to selected sample of SME of the Piemonte region, with focus on the manufacturing industry, carrying out *de-visu* interviews in order to elicit unbiased answers and deeper feeling about tacit perception from the subjects.

Among these selected firms are emerged some which offer a considered acceptable level of technological innovation satisfying the literature about Industry 4.0 and the Digital Twin precepts. These are analyzed by presenting the fit between the key aspects of the new innovative technologies and the economic and managerial advantages generated with a particular focus on the application innovative business model based on M2M economy and its relationship with business network.

Introduction

Nowadays, global economy is facing a period of great transformation. The macro-economic effect of globalization and the ease in the trading commerce, spread across the world, has led enterprises to take actions and adapt themselves to the changing environment; each day market demand for higher responsiveness and agility push all the players to research new enabling technology to keep the pace in order to survive in this context. For such a reason, a first step of development in IT solutions, in support to businesses, has brought great advantages facilitating internal and external communication.

According to these premises, a step forward, towards the digital transformation, has been conducted; a second wave of IT technology has begun to spread a new concept which propose to extend the already known industrial domain. Digitalization is not anymore intended a mere support to traditional enterprise strategies but rather aim to bring up ex-novo structures in industrial organization introducing innovative content. Such a great impact of what is defined as, Industry 4.0, influence business models, gives birth to the creation of new services and products and favors re-engineering of routines and processes.

In the Industry 4.0 context data acquire new dimensions over which to re-shape manufacturing ecosystem. Data assume a role in the corporate value chain, its contributions could affect already existent modules in the chain or suggest innovative one. Thanks to new computer science theory of Artificial Intelligence (AI), the innovative approaches towards managements of Big Data, the Augmented Reality (AR) and the Virtual Reality (VR), data acquire a crucial perspective to extract value from assets.

Among these solutions, it emerges the Digital Twin, a new digital paradigm. A loyal digital replication of a manufacturing system enabled by the use of real time information gathered through pre-existent and new technology such as artifacts falling in Internet of Things (IoT) environment. In particular will be introduced in this thesis an overall view to the actual adoption state of such a technology. To support such analysis, a survey conducted in collaboration with Istituto Mario Boella will provide a qualitative estimate with reference to Piemonte region.

In conclusion, a further analysis is presented with the aim to investigate the possibility of innovative business model introduced by the adoption of Digital Twin technology by proposing the main findings of a real case application scrutinized in the already mentioned survey and its relationship with the M2M Economy.

1 Industry 4.0

1.1 Brief introduction to Industrial Revolutions

Human history has been witnessed of the development of manufacturing industry in the last which has brought technology innovation and discovery to disrupt the existent manufacturing system in favor of new state of art one. Every step forward, in this sense, has acquired the name of Industrial Revolution. Until today, four Industrial revolutions have been recognized, each one with its own peculiarities but all of them with a common denominator which is innovation; this novelty conception affects not only technological paradigm (Dosi, 1982) of products and services but furthermore has the power to reshape preponderantly the industry layout.

This great potential is meant to offer opportunities for new form of businesses enlarging the offers spectrum in advantage to efficiency and quality. As a matter of fact, some common economic aspects are shared among the different revolutions (Jensen, 1993): costs tend to decline, productivity on average improves with significant drops but marginally shrink. Looking at the social side despite at first look it could resemble to have a negative impact on society, thinking about job replacement by machines for instance, it is often considered that mitigation of social welfare on the medium-long term is likely to occur (Jensen, 1993).

According to this premises, it is possible to describe chronologically as in Figure 1 the sequence of the Industrial Revolutions occurred.

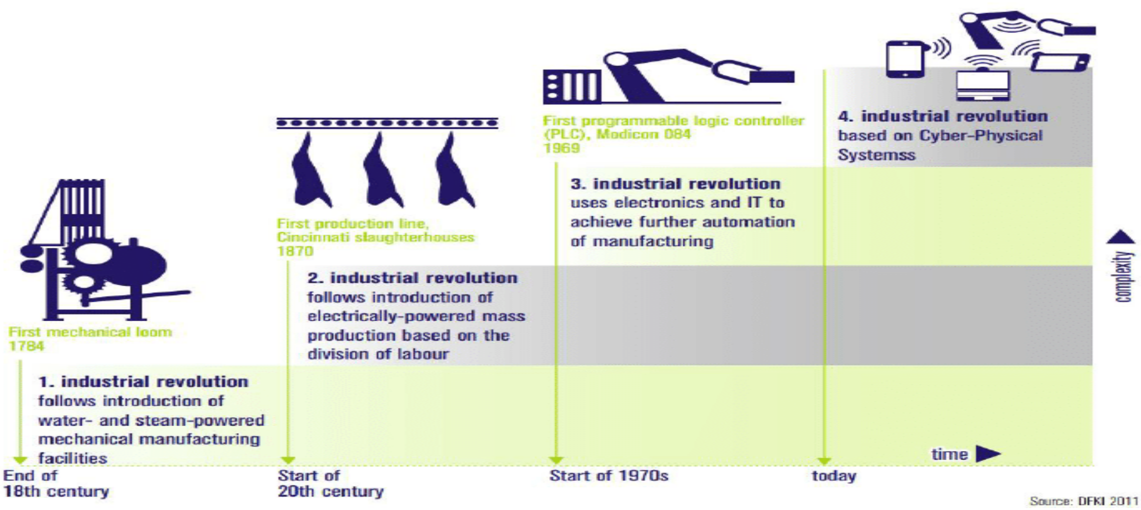


Figure 1: Timeline of Industrial Manufacturing revolutions (Ivica Veza, 2015)

In particular the first one, dated in 1784, deals with the new scientific discovery of source energy through exploitation of raw materials such as water but in particular characterized by the invention of the steam engine. Mechanization for the first time appears in manufacturing industry allowing to conceive a modern firm. The second one, dated in 1870, introduced the concept of mass production enabled by the exploitation of electrical power which significantly increased the production performance opening company to serve large portion of market and empower competitiveness; along with technological progress a social and organizational characteristic, within enterprise, contributed to leverage new production's technique, Taylorism. Serialization and assembly line significantly sustained the modernized business models. The third one, dated in the early 1970, is strictly related to new inventions in the field of electronics and obviously to its connected use of IT. The modern tools in that period stimulates manufacturing industry to re-interpret processes thanks to the brand-new capability to automate them. The firm began to be considered as full of automation potential environment, it is sufficient to think to the amount of documentation generated in business activities, and irrespectively to specific mansions even if in different divisions areas. IT technologies acquire a cross-functional dimension, fostering communication and information exchange either internally and externally to company. Such a novelty opened business scenarios previously unknown or not sufficiently effectives. Globalization economy phenomenon has meaningfully benefited from the communicative facilitation offered by IT solutions. The last and fourth Industrial revolution, which is intended to begin nowadays, take the name of Industry 4.0. It exploits the recent advancements in the field of telecommunication and interconnected systems to make headway in processes and production methods and to invent ex-novo business solutions. A further pace towards automation it will be accomplished thanks to robotics and intelligent system. Machines for the first time move towards self – independence, they are able to take decisions autonomously. This aspect another time in history suggest human being to think about the potential of technological progress and to shape over it, the manufacturing system it possesses.

1.2 Brief history of Industry 4.0

According to (Hermann, January 2016) the term Industry 4.0 born in Germany in 2011, becoming public with the aim to foster innovation and competition in the German manufacturing Industry (Kagermann H. W., 2011) in particular with reference to the initiative of "High-Tech Strategy 2020 for Germany". Subsequently, in April 2013 were published recommendations and guidelines for implementing Industry 4.0 (Kagermann H. W., 2013) , among those the description of what is meant by Industry 4.0 is state as follow: the future of business it is intended to become a global network of interconnected systems where machinery, warehousing system and production facilities will constitute what is called a Cyber-Physical System (CPS). These systems are called to exchange information among them autonomously. This independence, in the information processing, open to the possibility to establish self-determine actions triggers and enable machines themselves to directly control each other.

1.3 European innovation plans and Industry 4.0

European Union in the last decade has deeply reflected about the possibilities to guarantee innovation prosperity. One of the main principles upon which the EU has been constituted has its roots in the in the constitution of a single market. The objective on the long term is explicit, to become the largest market worldwide. For such a reason, to keep the pace with continuously growing digitalization in the globalized word, EU has decided to foster innovation policy which intend to ensure enhancement in manufacturing industry. Manufacturing is still one of the driving components of national GDP with reference to consumption (Attanasio, 1999) , both in terms of import and export finished goods; consequently, the focus in the formulation of an innovation policy went into this direction. It is concern of European policymakers to digitalize manufacturing industry with the aim to propose a new "Digital Single Market" (Stenkhen D. B., 2018) conferring competitiveness to the Eurozone and virtually becoming the largest digital unified market worldwide.
Until today European commission has approved a variety of plans which fall in the scope of the topic previously discussed. Among those a selection, according to their

relevance, can be identified and that together constitutes a "Central Framework programs for European innovation policy" (Stenkhen D. B., 2018):

Europe 2020 (European Council, European Commission)	Duration 2010–2020; Key strategy for funding intelligent, sustainable and inclusive growth; 7 flagship initiatives, including "Innovation Union", "Digital Agenda for Europe", "Industrial Policy in the Era of Globalization" and "Agenda for New Skills and Employment Opportunities"
Horizon 2020	Duration 2014–2020; EU funding programs for research and innovation; budget: ca. €77 billion
"Juncker Plan"	Since 2014; agenda of the new Commission; 10 core objectives
European Fund for Strategic Investments (EFSI)	Joint initiative by the European Investment Bank (EIB), the European Investment Fund and the European Commission; objective: overcoming weak investment in Europe through the deployment of resources for economically viable (but also high- risk) enterprises; funding of renewable energies and resource efficiency, but also small and medium-sized enterprises (SMEs)

The plan proposed by the European union aims to the re-industrialization of Europe, bringing the industry's share of total value creation from 15,1% (2013) to 20% of the GDP in 2020.

1.3.1 Digital Single Market

Previously it has been introduced the concept, promoted by European Commission, of a single unified market deploying the advantages brought by the digitalization. This strategy previses the coordination of national and regional initiatives and to address investments by supporting the creation of strategic partnerships and network. According to (Stenkhen D. B., 2018) this tactic hopes to generate around €50 billion in public and private investment in the digitalization of industry:

- 37 billion investment in Digital innovations
- €500 millions of European funds plus €5 billion of national and regional funding for so-called "Digital Innovation Hubs" (DIH)
- €6.3 billion for the first production lines of "Next Generation Electronic Components"
- €6.7 billion for the European Cloud Initiative

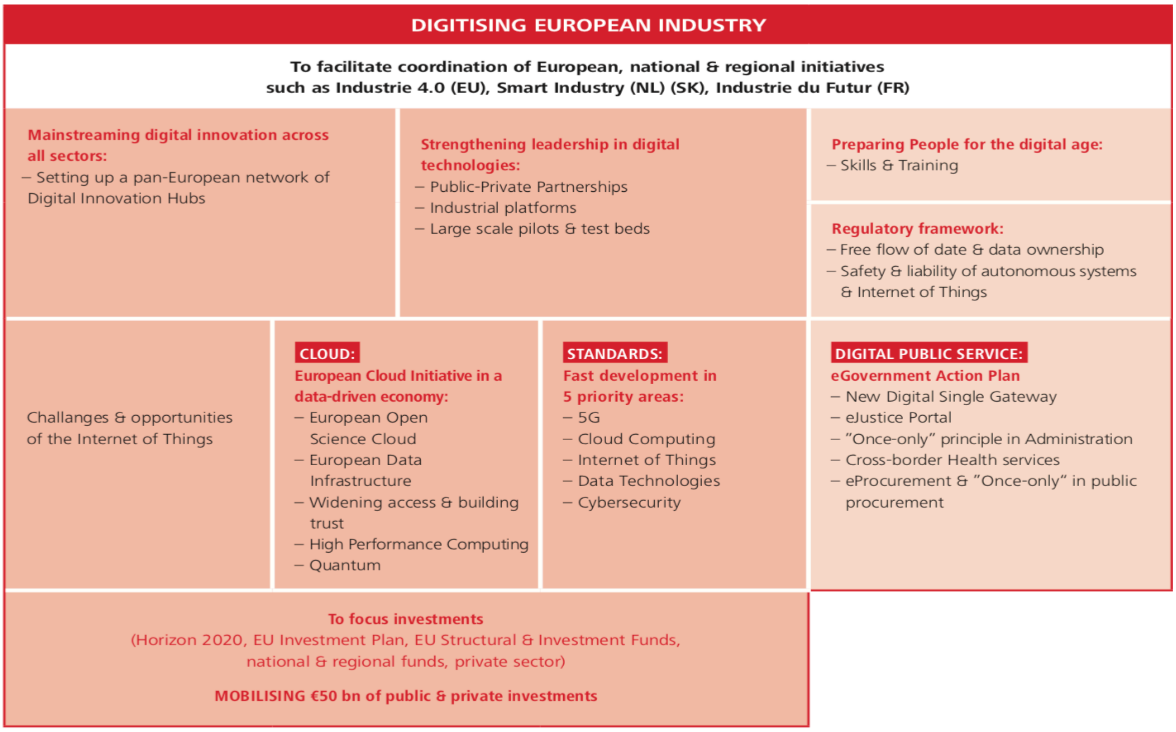
All these investments are structured by policymakers with three precise goals (Stenkhen D. B., 2018):

1. *Strengthening of political coordination:* the risk of atomization and the proliferation of actions in the deployment of public resources is remarkable. For such a reason, European authorities have concentrated its effort in grouping public resource. Furthermore, the value added proposed by EU bring frameworks and best practices in the field. This offer facilitates the creation of skills and the building of sharable knowledge.
2. *Investments in the capacity for innovation:*
   - **DIH - Digital Innovation Hubs**: the constitution of public and universities hub should attract SME in to take advantage of this as test environment and to experiment digital innovations.
   - **PPP - Public and Private Partnerships**: essentially European commission believes that to stimulate large - scale investment by the private sector it is necessary to build ad hoc partnerships between public and private sector. To be consistent with this belief the plan Horizon 2020 foresees the allocation of €5 billion in the development of PPP's plan, and a complementary € 15 billion in spending by the industry.

     It falls under this subject, the concept of platform. It is declared intention of EU to build integrated and cross-sector ecosystem over the new technological trend. Amon these, digital technologies such as: IoT, Big Data, Cloud Computing, Autonomous Systems and AI, give origin to specific PPP.
   - **Standardization**: To ensure interoperability among various system and compatibility among products, facilitate product development and ensuring the safeguard of consumer protection. All of these are kept under

consideration by public authorities about standardization becoming a crucial aspect standardization to be followed with attention. The focus in this technological context is concentrate in particular with regard to Data. Data protection and Cybersecurity intersect diversified aspect of EU rights deserving a greater consideration. Furthermore, other areas are subject of interest with respect to their high capacity in terms of infrastructure architecture and business capacity: 5G, Cloud Computing, and IoT.

- **Development of skills:** fostering research and activating updated courses in new technology could allow training for new skills with consequential born of new expertise but with more attention to raise the educational level about digitalization. Although, the main operativity margin about this area is still at national level, hence in the hand of the single member state which have deep divergence in terms of education each one, EU has started initiative to mitigate and enforce cooperation among nations by the promotion of, among the main one:
    1. Grand Coalition for Digital Jobs
    2. Digital Innovation Hub



Source: European Commission 2016.

Figure 2: High level EU directives for Industry 4.0 coordination among European countries, source European Commission 2016

1.3.2 Industry 4.0 in Europe

According to what it has been before mentioned, European Union has tried to foster innovation through the digitalization of the manufacturing industry through incentives plans with the aim to form the cultural base around the concept of Industry 4.0. This concept has introduced directives to be followed by each member state assuming different mutation depending on the policy peculiarity of each one, as shown in the map below:

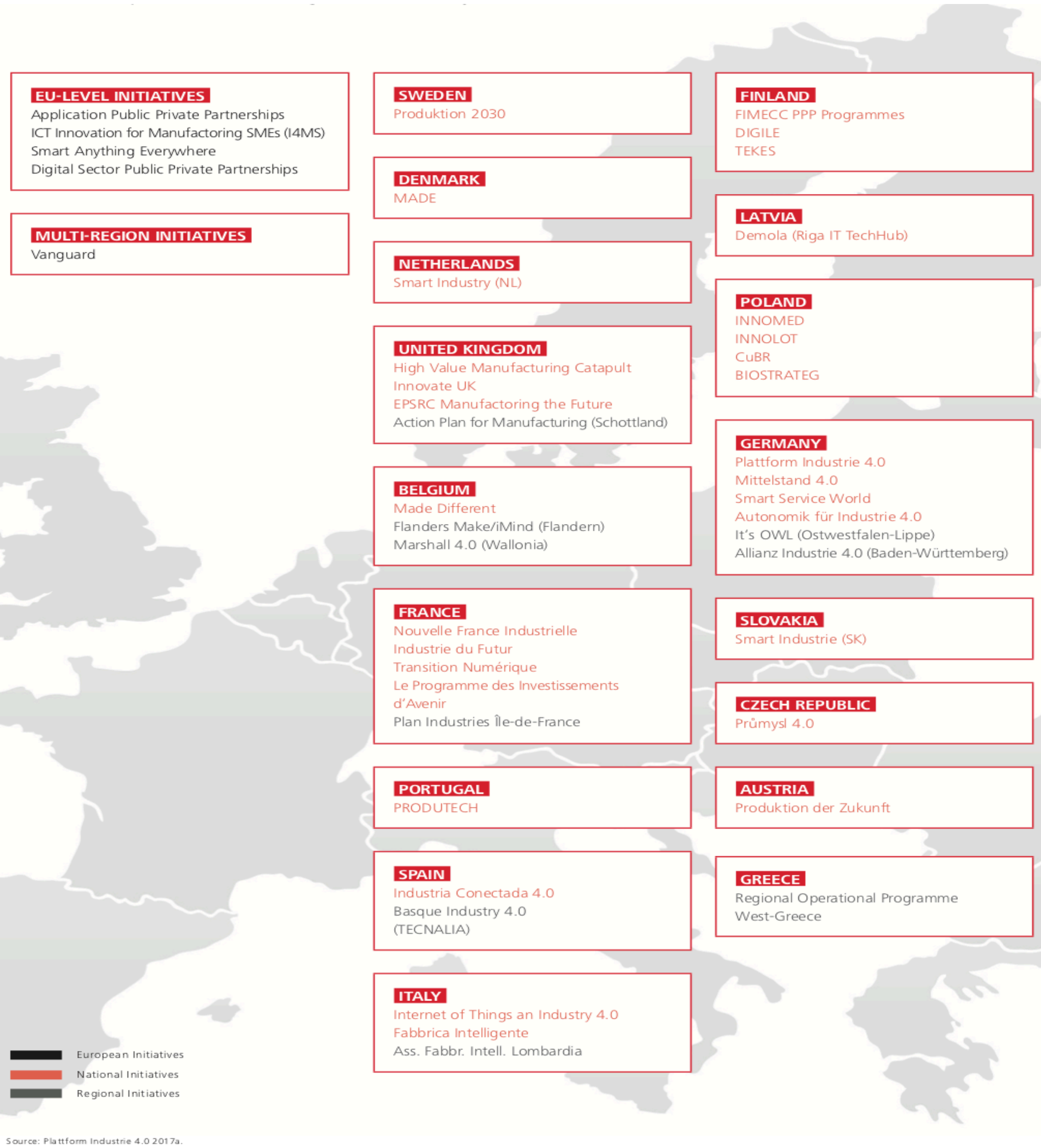


Figure 3: Overview of European initiatives for the digitalization of Industry (Stenkhen D. B., 2018)

1.3.3 Industry 4.0 in Italy:

In the context of the directives proposed and incentives plans offered by European Union each country member has structured its own development under Industry 4.0 perspective. With reference to Italy, a great contribution has been brought by the plan “Industria 4.0” introduced at the end of 2016.

The program defined aims to support the Italian manufacturing industry digitalization which can revolutionize the traditional manufacturing system and processes. Within this strategy the main intention is to encourage, the target SME, to adopt new technologies and to begin the educates a new work force towards new form of businesses.

The guidelines defined by Italian regulators wish to transmit the following principles:

- To operate in technological neutrality
- To intervene through horizontal actions and not vertical or sectorial
- To act on enabling factors

Under these assumptions strategic directives have been ad hoc designed

- *Innovative investments:* to stimulate private investments in the adoption of enabling technologies, in the scope of Industry 4.0 and to intensify the investment flow towards R&D and innovation spending
- *Enabling infrastructure:* to ensure adequate network infrastructure and to guarantee data protection, building collaboration for international interoperability standards.
- *Research & Competence:* to create needed competence and to stimulate research through ad hoc training
- *Awareness and Governance:* to spread knowledge about the potential of Industry 4.0 applications and technologies and to ensure public-private governance

It can be recognizable, at high level, a distinction of the plan made in two phases:

1. A *first phase* which began in 2016 ant which is concluded in 2018 concerning economic stimulus to the procurement of new machineries and software

2. A *second phase* which basically extends the time span of action of the previous phase but contemporary begin to build the competence framework to efficiently allow

the potential of the new acquired equipment; this second phase has been approved till the end of 2020

Both phases share the economic incentives structure except for figures and expiry dates, for such a reason in the subsequent section it will be described in details the main advantages offered in the "Industria 4.0" policy proposed by the Italian government in 2016 and after it will be exhibited how the new revised plan in 2018 has been modified for each specific economic measure: (Economico, Incentivi e strumenti di sostegno, 2018)

1.3.3.1 First phase

- *"Iper ammortamento":* fall under the innovative investment strategic directives, the objective of this instrument concern fiscal incentive in the adoption of new instrumental assets, either material or immaterial (software and IT system) which are functional to the innovation process of production systems. The advantages exploitable deal with the overvaluation of investment made in the previous defined instruments. In particular:
    - Over evaluation of 150% of the good purchased: in such a way the depreciation records an increase accounting cost of 250% with a corresponding decrease of taxable income. The SME adopting this tool gain meaningful advantage in terms of tax deduction.

Requirements needed to have access to "Iper ammortamento":

- the purchase of Instrumental assets, both material or immaterial have to be justified in the Industria 4.0 context, the focus regards highly innovative content.
- The benefits are extended to SME having firm income, therefore there are access constraint.
- The new machinery has to be functioning and *"interconnected"* to an already internal existing network functional to the management production system. It is specified, in this context, a set of rules to define what is meant by "interconnected" system:
    - Exchange of information with internal systems (planning systems, management of design and product development system) and/or external system (collaborative management and design systems

with customers, suppliers and partners), based on standards internationally recognized such as TCP-IP, HTTP, MQTT.

- Univocal identification of the new machinery, to determine the information origin, in compliance with international standards such as IP address.

- *"Super ammortamento":* similar to the previous description of the" Iper *ammortamento"* it falls under the innovative investment strategic directives, the objective of this instrument concern fiscal incentive in the adoption of new instrumental assets, either material or immaterial (software and IT system) which are functional to the innovation process of production systems. In particular:

  - Over evaluation of 40% of the good purchased: in such a way the depreciation records an increase accounting cost of 140% with a corresponding decrease of taxable income. The SME adopting this tool gain meaningful advantage in terms of tax deduction.

  Requirements needed to have access to "Super ammortamento":

  - Both SME with firm income, owner with firm income or freelance can access this fiscal incentive. In this case the constraints present in Iper Ammortamento are less narrow.

- *"Nuova legge Sabatini":* it falls under the innovative investment strategic directives. The objective of this instrument concerns a public subsidy to access financing facilitation to the purchase of new instrumental machinery. The facilitated financing it is allowed only through the financial institutions in agreement with the Italian Economic Development Ministry. The main financial institutions considered are banks and leasing service company. The main contribution regards the interests accrued by the total financing amount calculated on the depreciation plan (on a semester basis) to the new machinery acquirement. The maximum annual interest rate reimbursed concern 2.75% for 5 years.

- *"Fondo di garanzia":* it falls under the innovative investment strategic directives. It allows firms to access financing without the need of the major financial guarantees. Financial guarantees for financing in the context of Industry 4.0 scope are assured by the fund for to a maximum of 80% of the guarantees needed. To access this form of financial aids the Ministry of Economy and Development has imposed the following requirements and limitations that needs to be respected:

- Financing period: the temporal horizon should last at least 18 months and at most 10 years
- The plafond of the financial guarantees ensures collateral for a maximum of 2,5€ million without limitations in terms of financial operations: different financings could exploit the guarantees fund cumulatively until the threshold.

- *"Credito di imposta sulla Ricerca e Sviluppo":* it falls under the Research and Competence enhancing and Awarness and Governance strategic directives. The main objective concerns the offer of economic support, through the form of tax credit, especially to small and medium firms, to earmark part of resources towards R&D. R&D budget allocation often suffers of restriction in limited dimension firms, because of costs prioritization. In practical terms, MISE is available to assist firms with the following modalities:

  - The tax credit is proposed with an annual maximum of 5€ million for each beneficiary. It is recognized at condition that the overall R&D expenditure, concentrated in the tax credit period of interest, amounts to at least 30.000
  - The tax break it is accredited automatically through the tax declaration
  - A tax credit of 50% in case of expenditure for one of the following:
    1. high specialized human resources and with research contract
    2. depreciation expenditure for laboratory instruments
    3. expenditure related to patent acquisition or license

- *"Patent box":* it falls under the innovative investments, Research and Competence enhancing and Awareness and Governance strategic directives. The scope of the instruments address innovation in patents and intellectual property.

In particular tax authorities renounce to part of contribution deriving from sales and license profit.

- *"Incentivi per Start Up e PMI Innovative":* it falls under Innovative investment, Awareness and Governance strategic directives. This financial instrument consists in tax relief for investors involved in financing activities of SME and startup.

- *"Credito d'imposta per la formazione":* it falls under Research and Competence enhancing and Awareness and Governance strategic directives. The main concern of this form of tax credit is to subsidize small and medium enterprises in the acquisition of new competences in the scope of the new enabling technology of Industry 4.0, such as:

1. Big Data and Data Analytics
2. Cloud and fog computing;
3. Cyber security;
4. Simulations and Cyber physical systems
5. Rapid prototyping
6. Augmented reality (AR)
7. Advanced and Collaborative robotics
8. Human-Machine interfaces
9. Additive manufacturing
10. Internet of Things (IoT)
11. Digital integration of industrial processes

It will follow in section 1.3.4 a dedicated to the description of the enabling technologies.

The tax credit amounts to 40% of the training expenses in one of the above cited topics. Each beneficiary could benefit until a maximum of 300.000€.

- *"Accordi per l'innovazione"*: it falls under the innovative investment and under Research and Competence enhancing strategic directives. Financial advantages are assigned in function of the project proposal which requires to be in *scope* of the enabling technology foreseen by the European Commission program Horizon 2020:

1. ICT (Information and Communications Technology)
2. Nanotechnologies
3. Advanced material
4. Biotechnologies
5. Manufacturing and advanced transformation
6. Space
7. Technologies intending to address the objectives defined in “Sfide per la società” foreseen in the program Horizon 2020

The project proposed to be considered eligible, should respect:

- cost constraints: a minimum of 5€ million and a maximum of 40€ million
- time constraints: the project should last at most 36 months

The financial benefits obtained through this financing instrument are composed as follows:

- Participation to expenditure: reimbursement of 20% of cost involved in the project
- Subsidized loans: a maximum financing of 20% of declared cost, defined preventively in the agreement subscription phase

- *“Contratti di sviluppo*”: it falls under the innovative investments and under Research and Competence enhancing strategic directives. This form of incentives applies to strategic plan of considerable dimension in: industrial field, environmental protection field and in hospitality/tourism field. The financing amount has a limitation of 20€ million.

1.3.4 Industry 4.0, Enabling technologies:

So far, the focus has been over the economic incentives foreseen by the Industry 4.0 plan and the infrastructures in the telecommunications context. They contribute significantly to stimulate the industry in the adoption of new technologies enabling the economic development in multiple industries of the country. But which are the most significant technologies that raise enterprises interest?

According to (Mohd Aiman Kamarul Bahrin, 2016) the enabling technologies macro areas related to the Industry 4.0 can be grouped as shown in Figure 4

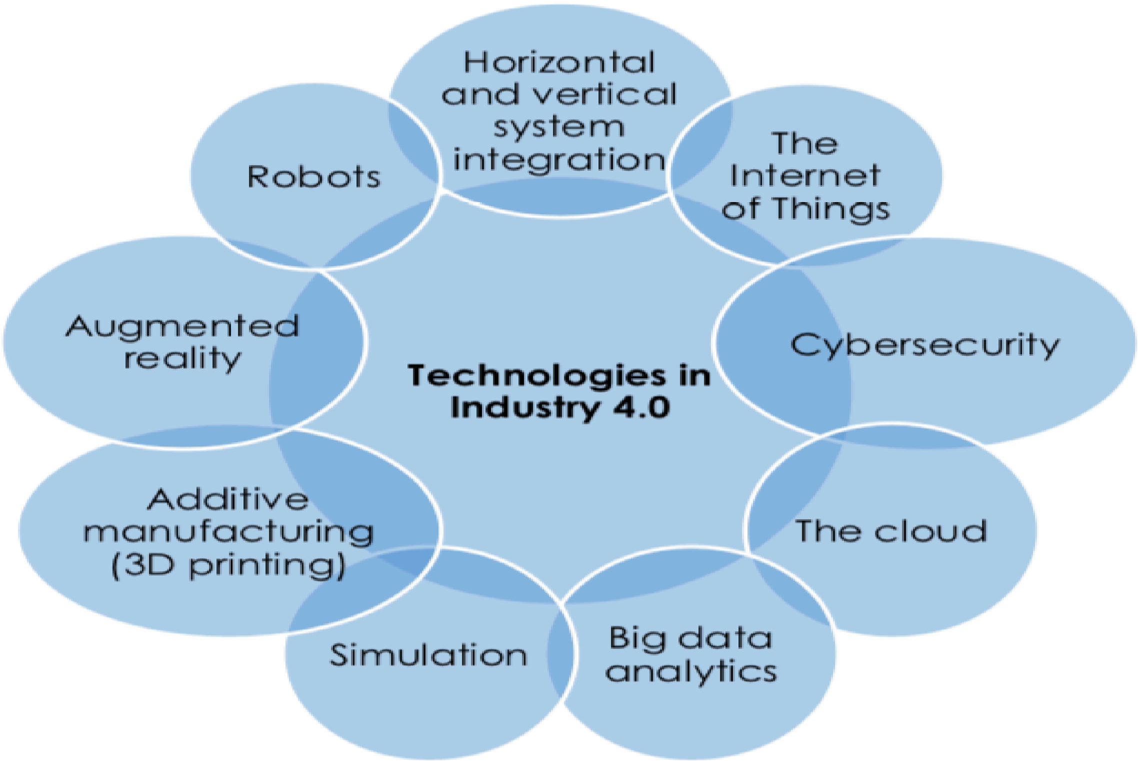


Figure 4: Enabling technologies macro areas

Beginning from the enabling technologies macro areas identified it has been conducted an in-deep research presented below:

1. *Big Data and Data Analytics:*

thanks to the spread of electronic devices and interconnection among them, data proliferation is continuously increasing. Each day data is even bigger than ever before. Thanks to growing volumes of data, the possibility to enrich and validate statistical model is acquiring a solid dimension (Russom, 2011) . The terms Big Data refers to the huge amount of data produced by human communications, enterprises back end systems, sensors, actuators and any other system able to transmit or record data. Nevertheless, not all data produced could be considered Big Data. According to (Russom, 2011) there are 3 constituting element that grant the classification of Big data as clarified in

Figure 5

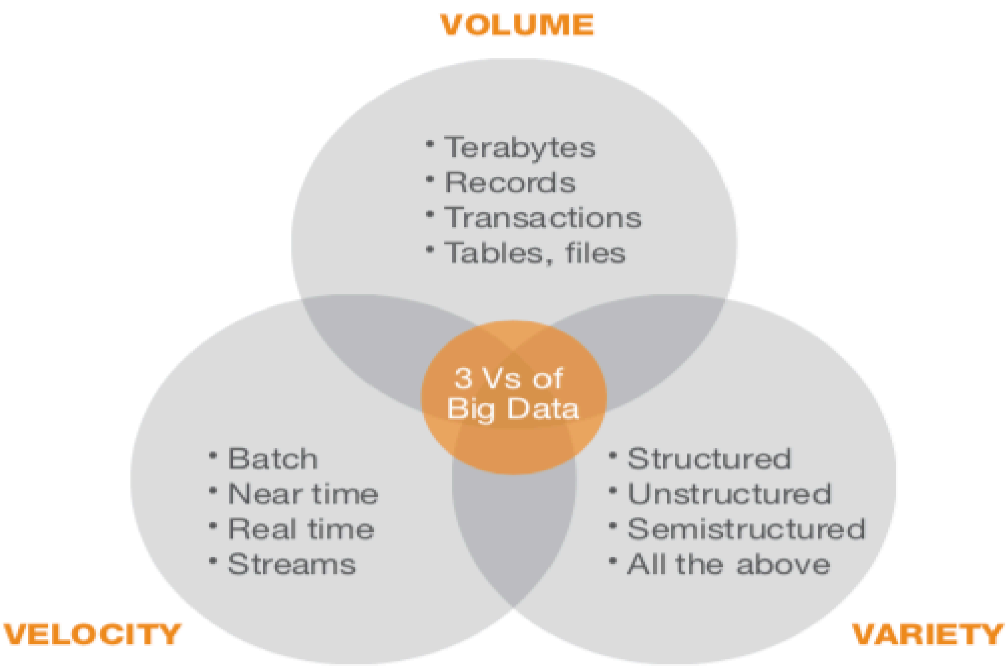


Figure 5 : The three V's of Big Data (Russom, 2011)

Big Data analytics instead are referred to the advanced analysis techniques build up around the complexity brought by a massive data management. Nowadays, the term Big Data analytics it is still confusing, most of the people refers to this technique using general term analytics, large data analytics or BI among the others.

The mixture of Big Data and Big Data analytics introduces new benefits under different perspectives:

- *Economics of analytics are more embraceable than ever*: the cost of data storage is continuously decreasing

- *New insights about the business:* the elaboration of new big data sets brings potential discoveries and new business opportunity enabling to look at the business under different perspectives.

- *Reliability even in presence of raw data:* because of the huge amount of data and advanced techniques extraction of significative data even with data set which are not properly refined or still not-normalized. The poor-quality data tolerance becomes crucial in the investigation of information in that model that generally needs outliers and out of the scope data to produce better results.

2. *Cloud and fog computing*:
among the most noteworthy technologies included in the industry 4.0 terrain Cloud Computing carries practical and immediate advantages to firms even in short term.
According to the NIST (National Institute of technology) definition: "Cloud computing is a model for enabling ubiquitous, convenient, on-demand network access to a shared pool of configurable computing resources (e.g., networks, servers, storage, applications, and services) that can be rapidly provisioned and released with minimal management effort or service provider interaction. " (Peter Mell, 2011).
Regarding the befits introduced by Cloud computing solutions, 5 macro categories could be identified:

- *On demand self-services:* customer can access the desired service autonomously without additional human interaction by the service providers.

- *Data ubiquities through broad network access:* data can rely on multiple heterogenous access sources (mobile phone, servers, laptops) through a common standard shared platform

- *Resource pooling:* a great advantage of the cloud computing in the concentration of computing resources in the hands of the service providers. Customers have no control nor the knowledge of where the computing capacity is supplied, the location independence ensure a higher level of security

- *Rapid elasticity:* the flexibility in scaling customer demands transfer in the cloud computing solutions the capability to guarantee high performance standards

- *Measured Service:* efficiency in service provision is enhanced. At least at higher level a more efficient modality to service offering on demand allow the precise storages calibration, computing capacity, bandwidth occupation and active user accounts

Among the possible Cloud Computing service models:

1. *Software as a Service (SaaS):* the software run on cloud infrastructures and customers can easily access the service through whatever devices by the use of client interface such as Web browse application or dedicated application. Customer are completely obscured about network, servers, operating systems, storage or even individual application capabilities.

2. *Platform as a Service (PaaS):* the service provider offers the client a set of libraries, service and tools to build its proper application solution. The client in this manner is obscured from networks, servers, storages and operating systems

3. *Infrastructure as a Service (IaaS):* the client benefits from the use of the infrastructure but is able to develop and use different software and operating systems. The new solution

Fog computing: according to (Luis M Vaquero, 2014) "Fog computing is a scenario where a huge number of heterogeneous (wireless and sometimes autonomous) ubiquitous and decentralized devices communicate and potentially cooperate among them and with the network to perform storage and processing tasks without the intervention of third parties. These tasks can be for supporting basic network functions or new services and applications that run in a sandboxed environment." It can be furtherly specified that the Fog should be considered an advanced abstraction level with respect to the Cloud. In the literature the Fog often, under the architectural design perspective, has conceived as set of interconnected mini cloud at the edge. The advantages of this architectural scheme intend to remarks are considerably noticeable in terms of security, data storage decentralization, data processing and speed in response. One of the major obstacles faced by the realization of the Fog, regards network interoperability among the multitude of devices, which are estimated to become 50 billion by 2020 (Luis M Vaquero, 2014). The complexity introduced by the massive number of actors in the network will require the development and the use of dedicated software, known as SDN (Software Defined Networks) able to replicate a virtual network, NFV (Network Function Virtualization) offering a standard assigned configuration to each single device . In conclusion the Fog is to be considered a great innovation considering the potential of the IoT technologies, that will be thereafter developed in this thesis.

To get a more explicative insight about Cloud Computing and Fog Computing differences

Features	Cloud	Fog
Latency	High (eventual consistency)	Low (locality)
Service access	Through core	At the edge/ on handheld device
Availability	99.99%	Highly volatile/ highly redundant
# of users/devices	Tens/Hundreds of millions	Tens of billions
Price per server device	$1500-3000	$50-200
Content generation	Central location	Anywhere
Content consumption	End devices	Anywhere
Software virtual infrastructure	Central corporate servers	User devices

3. *Cyber security:*

   With the concept of Industry 4.0 and the concept of continuous interconnected systems within firms, security becomes a crucial aspect to keep constantly under observation. Although security is a per se delicate topic, in the Industry 4.0 acquires a higher level of worry towards its management. Previously, information security was focused on the sensible data protection with regards to people identification and preservation of enterprise know how. With the advent of the Smart Factory, manufacturing firm with digitalized interconnected machineries, processes become automated and monitored through dedicated hardware and production control software (Agnieszka Radziwona, 2013). Every machinery and device involved in the process aim to be digitalized and interconnected producing considerable amount of data. For such a reason the process becomes vulnerable to cyber-attack and a new risk component never considered before it begins to be kept into consideration. Cyber Security in this context concern the best practices, tools, risk management approaches, guidelines, insurance policies and techniques necessary to face and address the new threat in IT security with particular concern to the Internet and network exposure of internal systems. (Rossouw von Solms, 2013).

4. *Cyber physical systems:*

   with the increasing availability and affordability of sensors, actuators and other data acquisitions systems and computer network, firm has started to concern competition and new methodologies in the for high-tech implementation in manufacturing and productive systems. For such a reason according to (Jay Lee B. B.-A., 2015) "Cyber-Physical Systems (CPS) is defined as transformative technologies for managing interconnected systems between its physical assets and computational capabilities". CPS are generally categorized by the definition of 5 layers architecture named the 5C as shown in Figure 6, but more in general CPS bear two innovative functional elements:

1. *Real time information:* the contribution of interconnected systems allows data information to be shared instantly or even so.
2. *Advanced data analytics:* as mentioned in the previous section related to Big Data and Big Data Analytics, with huge number of data further steps towards new insights about processes improvements or new business opportunities is empowered

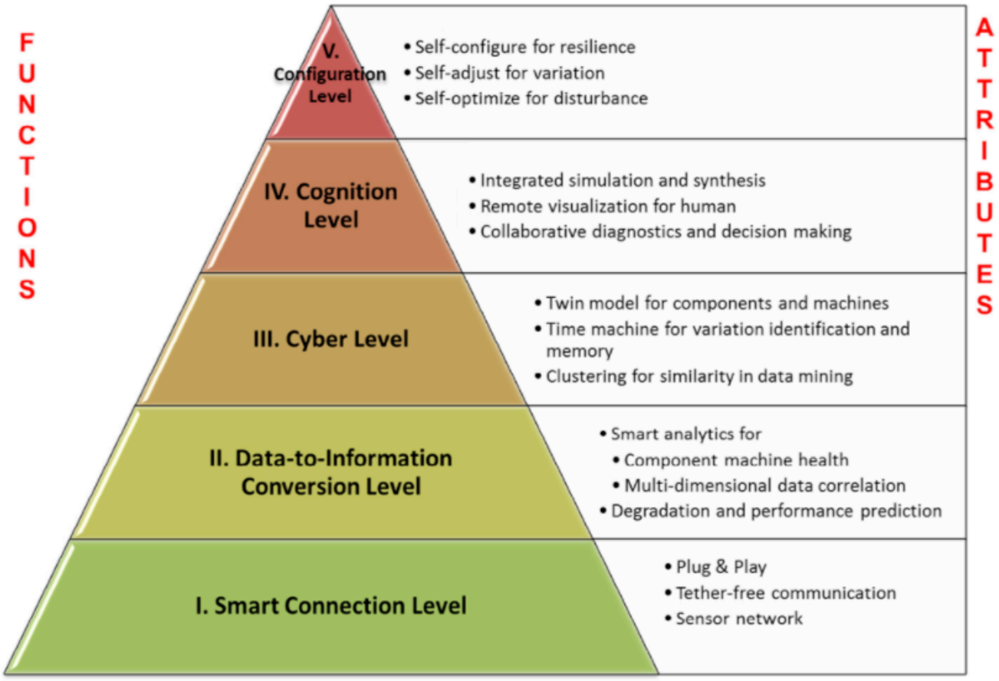


Figure 6: The 5C's architecture for implementation of Cyber Physical Systems (Jay Lee B. B.-A., 2015)

The pyramid helps the reader in following the steps the implementation of a CPS should follow to be considered as such. With regard to “Attributes” described in Figure 6 a set of enabling factors to the functionalities described in the “Function”.

As mentioned in the previous chapters data assumes relevance in the adoption and in the implementation of new dedicated technologies, for such a reason in figure 5 it is presented a practical scheme of the functioning of a CPS through the data flow analysis to get an insight of the qualitative conveniences the CPS architecture could lead to

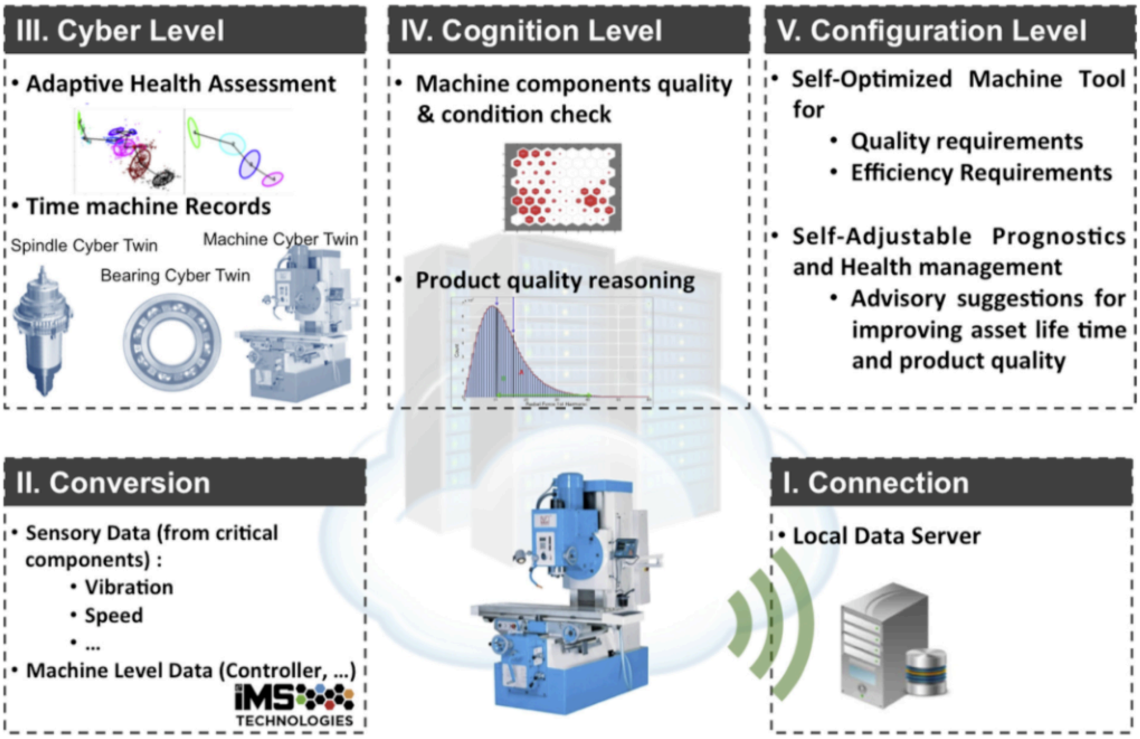


Figure 7:The flow of data and information in a CPS enabled factory with machine tools in production line based on 5C CPS architecture. (Jay Lee B. B.-A., 2015)

5. *Augmented reality (AR) & Virtual Reality VR:*

augmented reality AR allows the user to see virtual objects super-imposed or composited to the real world (Azuma, 1997) . The main innovative contents introduced by AR deals with:

- Real and Virtual world combination
- Real time interaction
- 3D registration

These 3 components explain the potential of the AR technology. The potential of AR is commonly enabled by the visor technology, even if in the recent years a new brand device as started to introduce a new human interaction with the AR technology, the smartphone application.

With reference to manufacturing and productive systems the possibility to visualize virtual objects in real space offer incomparable advantages in terms of components design and employee training. But not only, in the products and object conceptualization phase it could be employed. Specifically, for the manufacturing industry, an emerged use case concern the use AR technology regards the equipping methods for machinery. The simulation of real dimensions of components and ad hoc tools allow operators to substitute constituent's equipment, in near real time, with the most appropriate pieces.

Virtual Reality (VR): the VR technology falls under the area of the Artificial Intelligence and Computer Engineering, it mainly concerns with the virtual simulation of a system. The computer simulation of the system supports its replication either real or allegorical allowing a user to simulate in near real time the operations and to observe the effects (Wang G. Gary, 2002). To reconcile the technological potential of VR to the manufacturing industry it can be easily recognizable the noteworthy advantages in terms of design and cost savings. The process and components architecture simulations offer critical advantages in terms of:

- Cost Savings: R&D expenditure and trials components cost are avoided
- Reduce time to market in products and production planning
- Enhance product quality: the ease to check and identify production errors foster the research of a better quality in the same amount of time
- Manufacturing process time: by the simulation of productive system it becomes feasible to anticipate eventual bottlenecks or incorrect components functioning. Thanks to virtual monitoring the ability to improve production efficiency is reinforced
- Prototyping design facilitation: the possibility to connect CAD system to VR enable new scenario in the design product capacity. The CAD 3-D model can be modified before the component goes in production, Figure 8.
- Productive process maintenance: thanks to simulation form machinery's components to entire production lines, the maintenance process obtains a relevant support. Simulation test and stress the resistance of components a priori and enable monitoring with long term horizon.

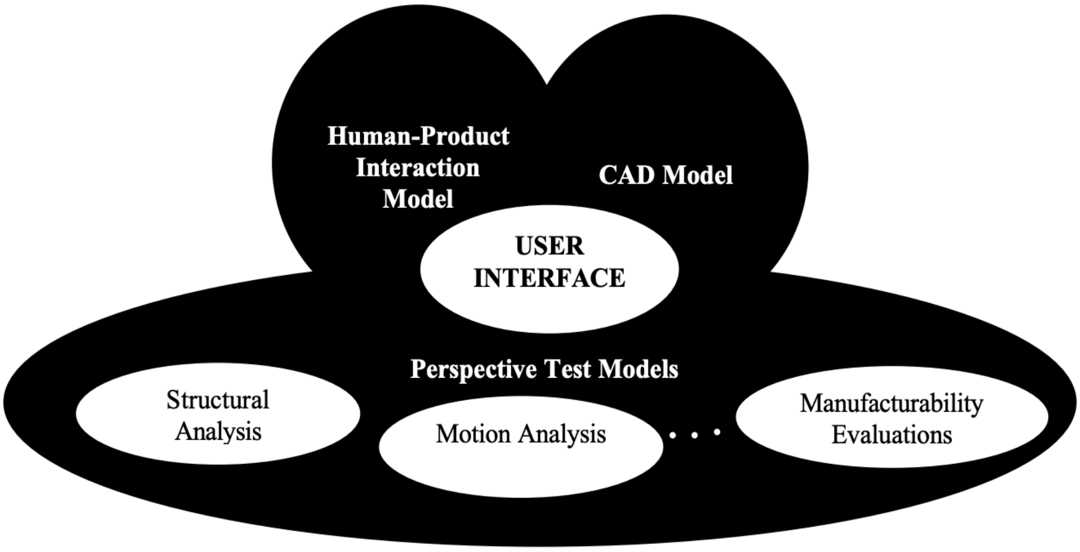


Figure 8 Components of Virtual prototype (Wang G. Gary, 2002)

6. *Advanced and Collaborative Robotics:*

In the recent years, the push towards process and production automation has led academics and industries in research and development activities with regard to Robotics subject, namely the engineering branch that concern the conception, design, manufacture and operation of robots. Although, ethical and regulatory issues surround some robotics application, in particular with reference to humanoids, the idea to adopt robots with reference to industrial automation is becoming widespread. Combined to industrial automation robots another noteworthy robotics category is beginning to arise interest in this context, is collaborative robotics. Collaborative robotics, according to (Mohd Aiman Kamarul Bahrin, 2016) assumes an innovative connotation in the use of robots; human and robots' collaboration is enabled by robots dedicated to worker's assistance. Practical use cases deal with the support of robots to human in activities such as production, logistics, and office management. Within this context a point of attention is brought by the human interactions with robots. The first use case application regards the human-robots collaboration in manual tasks, the robot's arms help in manual duties advance several advantages, among all: it reduces human-labor physical efforts and ensure high job security standards levels Figure 9

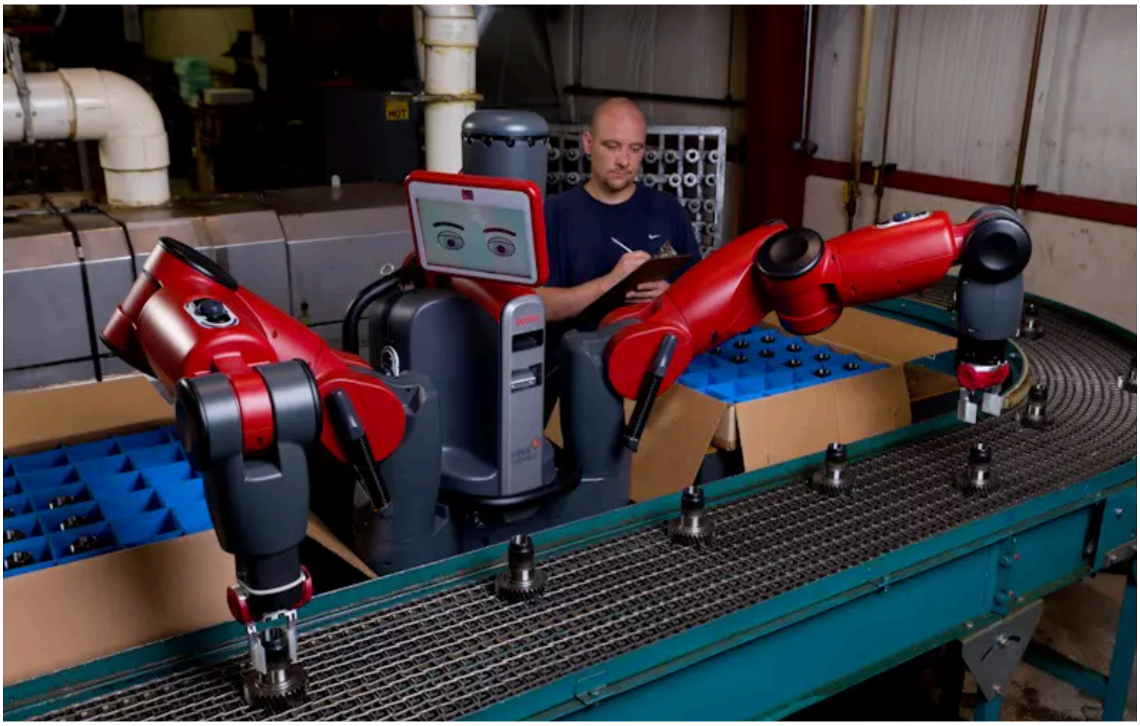


Figure 9: Human-Robot interaction in daily operation routine

In addition, Innovative human interfaces facilitate the control of robot's activities and introduce improvements in job's quality of workers. To support this latter assumption a common use case offered concerns the remote control made by the use of Webcam. This solution confers the possibility to the worker to correct robot's mistakes and monitor activities to have an overlook about the possible process improvement.

7. *Additive manufacturing:*

Although in the recent period the term Additive Manufacturing have been on the mouth of expertise, the technologies foreseen by AM have been around for decades. As matter of fact, additive manufacturing includes technologies concerning the virtual design of components and parts realized by autonomous production machines.

The innovative contents recently proposed in the fields of materials and construction's techniques significantly contributed to the market appeal of the AM technologies.

For a better explanation of what exactly is meant by AM a brief introduction to some of the main technologies could be useful. The cohesion among 3D CAD design software (it enables virtual design of components and parts) and 3D printing, constitutes a modern approach to prototyping: namely the potential to realize complex geometries, high adaptability to standards and reduced time to realize the desired customized prototype. Although, 3D printing carried out highly innovative content, the lengthened production time and the costly materials are considered obstacle with reference to standardized mass production. As matter of fact, the melted material constituting the objects printed reduce the usage of the technology for mass production because of its elevated cost. In addition, a relevant limitation showed by 3D printers concern product dimension, the object produced results too small for most of the components needed in specific industries. For such a reason other recent technological trends, part of AM, intends to replicate some aspect of 3D printers in large scale or with reduced material cost and production time with a clear tradeoff in customization.

According to this premises AM clearly represents a pillar of the Industry 4.0 concepts: digitalization of analog process and interconnections between virtual and real environment.

8. *Internet of Things (IoT)*

Nowadays, IoT represents one of the most discussed technology trends among academics and industry. IoT made its first appearance on the Gartner emerging technologies trends in 2011 and still today remain in the this cited technology as shown in Figure 10

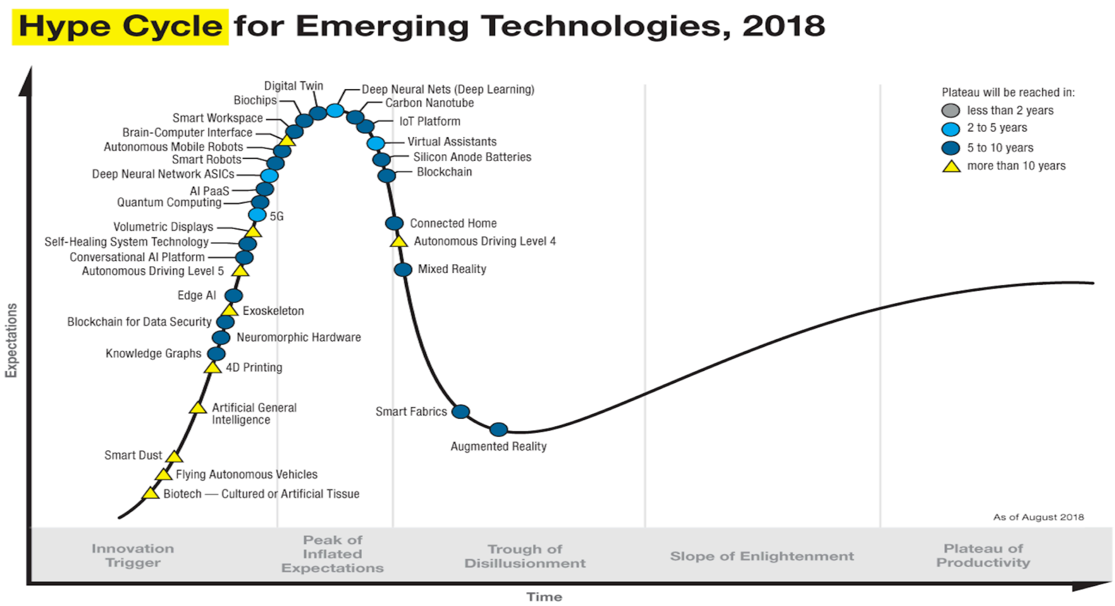


Figure 10: Emerging technologies Gartner Hype Cycle 2018, source Gartner, (August 2018)

According to Gartner by 2020 there will be more than 20 billion connected sensors and endpoint this enable the vision and concept at the basis of the IoT technologies. A broad variety of definitions of IoT can be found among in academic literature among which it deserves to be mentioned:

The RFID group defines IoT (Jayavardhana Gubbi, 2013) : "The worldwide network of interconnected objects uniquely addressable based on standard communication protocols."

Cluster of European research projects on the Internet of Things defines IoT (Woelfflé, 2010): "Things are active participants in business, information and social processes where they are enabled to interact and communicate among themselves and with the environment by exchanging data and information sensed about the environment, while reacting autonomously to the real/physical world events and influencing it by running processes that trigger actions and create services with or without direct human intervention."

According to (Jayavardhana Gubbi, 2013) IoT can be defined as: "Interconnection of sensing and actuating devices providing the ability to share information across platforms through a unified framework, developing a common operating picture for enabling innovative applications. This is achieved by seamless large-scale sensing, data analytics and information representation using cutting edge ubiquitous sensing and cloud computing. "

McKinsey define the IoT according to (York, 2015, June) as: "We define the Internet of Things as sensors and actuators connected by networks to computing systems. These systems can monitor or manage the health and actions of connected objects and machines. Connected sensors can also monitor the natural world, people, and animals"

Thanks to the cited definition it is possible to grasp the potential of the IoT technologies which aspires to become the web3 (ubiquitous computing web), the third version of the web after the www (static web pages) and the web2 (social networking web). Interconnection between sensors, actuators and any kind of devices are nowadays reinforced by the advancements in network power. With the advent of the 5G the network speed will hopefully sustain the massive amount of data that the interconnected devices will produce. Other key technologies for IoT solutions are represented by passive RFID technologies and NFC.

Looking at the economic potential of the IoT solutions proposed by McKinsey IoT solutions intends to serve both the B2C and the B2B markets with a focus on the latter as long as it could bear doubled value. Looking at Figure 11, the distribution of market potential related to different industries aggregated estimated forecast of the overall market between \$3.9 trillion - 11.7 trillion by 2025, roughly the 11% of the world economy based on the world bank projection of \$99.5 trillion per year in the global GDP in 2025 (York, 2015, June).

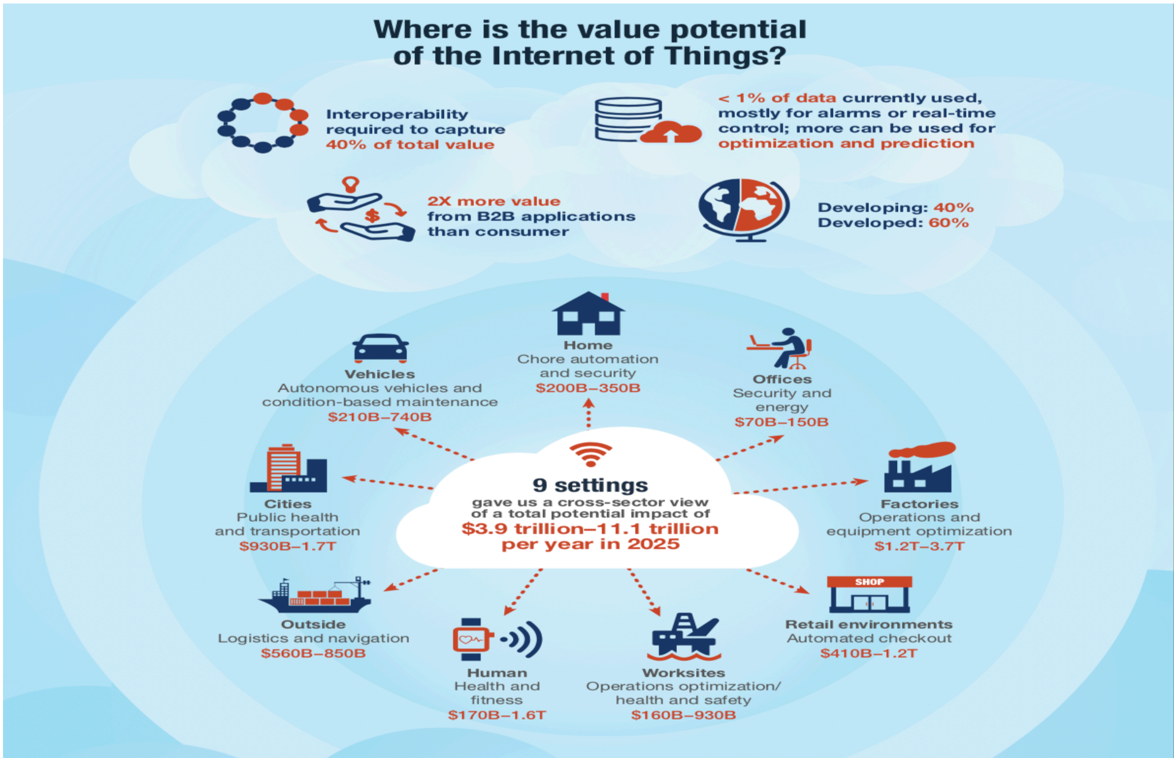


Figure 11: The internet of things: mapping the value beyond the hype, source McKinsey Global Institute (York, 2015, June)

9. Internet of Services (IoS)

The Interne of Services it is intended to be a modern concept of platform that can collects and provide the multiplicity of services that the new Industry 4.0 enabling technologies are creating. It is important within this context to keep in mind that economy is shifting to a majority component of manufacturing to a mixed economy with composed in prevalence by services (Jorge Cardoso, 2008, June) .Thanks to this assumptions IoS can be put under the perspective of a marketplace where services can be traded as long as done for tradable goods on eBay. Thanks to the creation of a marketplace platform the IoS offer the opportunity to all the industries to explore new business model opportunities. Consumers and suppliers could match the provisions and consumption of services in an aggregated environment where the best offer could be taken. The results of the marketplace and shared platform proposes noteworthy advantages with regards to the opportunity to create business network with ease. The provision of services can be offered by multiple suppliers that can differently contributes to a single requested service by a single customer. On the other hand, multiple customers can aggregate their request of services to obtain a favorable price by a single supplier which can benefit from economies of scale and service provision planning.

1.3.5 First results of Industry 4.0 in Italy:

1.3.5.1 Italy in the European Context

According to the report published in March 2018 by the National institute of Statistics, ISTAT: Italy has followed the trend towards firm's digitalization. By making international comparisons, it can be possible to confirm it although the growth does not seem to fill the gap with most of the other European countries, one of the indicators kept into consideration is the enterprises web presence, as follow in Figure 12

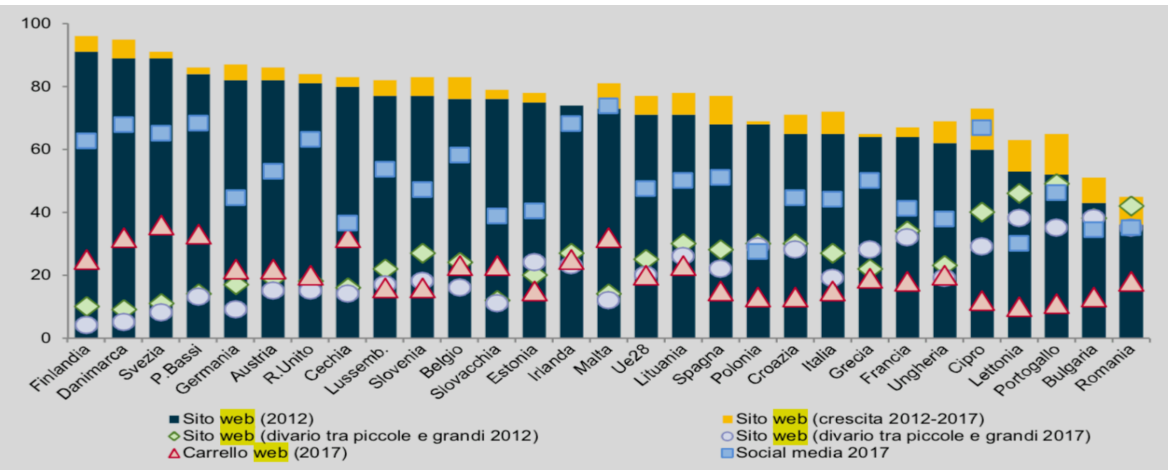


Figure 12: Firms Web presence UE - Years 2017 and 2012 (firms' percentages; firms with at least 10 employee) (Istat, 2018)

These following histograms underline the discrepancy in the adoption of enabling technologies in the context of digitalization. This inconsistency is mainly due to scarcity of infrastructure investments. To elicit this consideration, its ca be analyzed the broadband coverage and Internet velocity that offer a significant insight with regards to infrastructure. As shown in Figure 13, over the national's territory, it seems that a positive trend regarding the adoption higher internet connection speed is affecting the country,

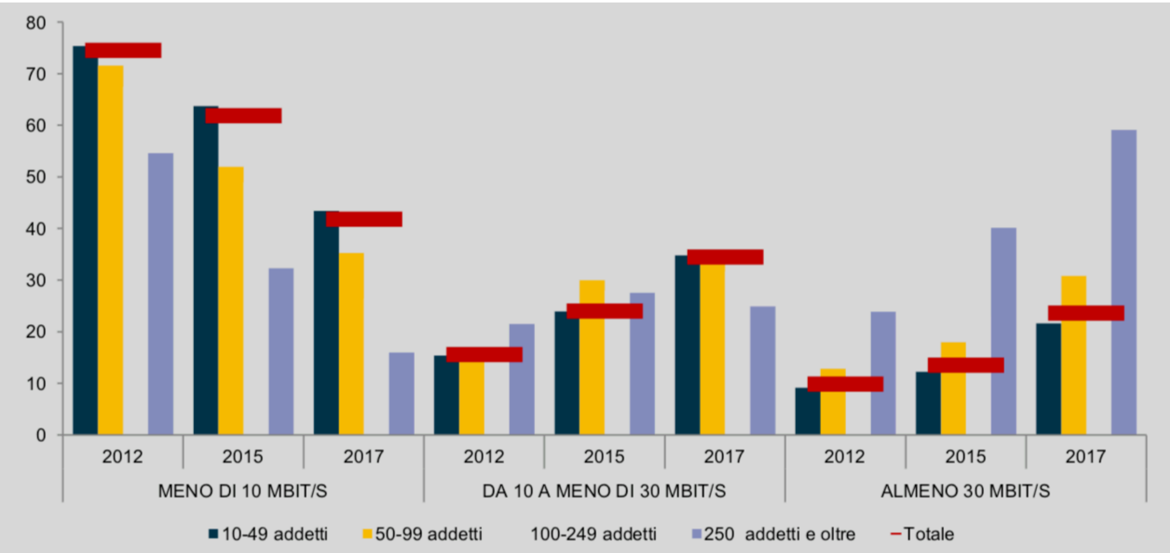


Figure 13: Internet fixed broadband connection speed, years 2012-2017 (Istat, 2018). Source: Istat: technological estimate of enterprise ICT technology

Despite of it, Figure 14 deliver a more realistic perspective. In the European context Italy results to be rearward. The underdevelopment attitude towards infrastructure investments it is deep for instance compared to the top European countries in the Nordic region.

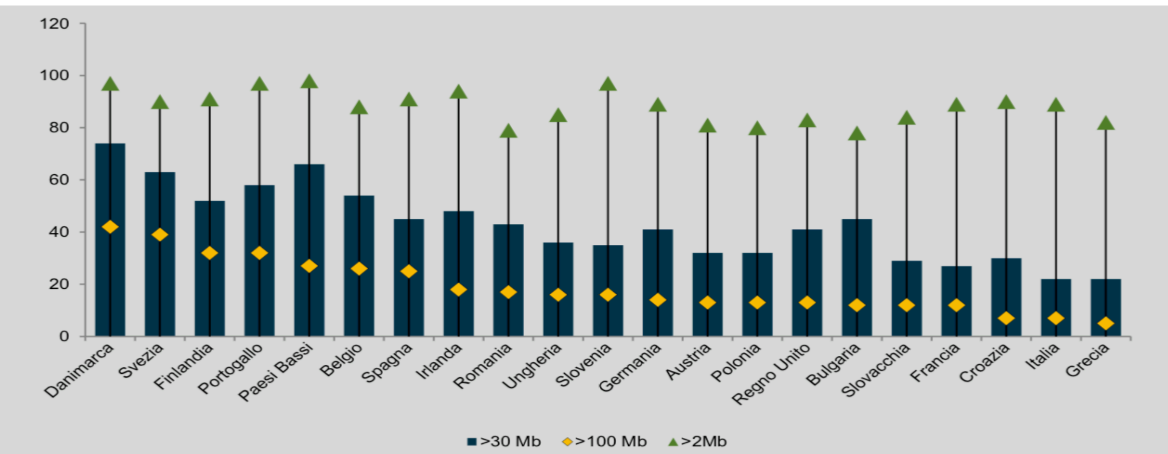


Figure 14: Large broadband and ultra-broadband in the enterprises, year 2017 (Istat, 2018). Source: Eurostat ICT usage and e-commerce enterprises

In addition, another aspect shows digitalization development delay in of the Italian country: the use of data.

Nowadays, data possess increasingly importance in the productive ecosystem. The new dimension of interconnected systems allows firms to intensify the effort towards interoperability of business units and a creation of innovative cross-services and process re-engineering. For such a reason software dedicated to specific activity should be integrated in modern cross-functional software systems used by all business units, such as:

- ERP - Enterprise Resource Planning: modular software systems which support business management in decision making. Each module supports functional areas such as: sales, marketing, accounting, financial, human resources, service and maintenance, inventory management and transportation and e-business (Alshawi S., 2004).
  ERP systems replace complex and sometimes manual interfaces between different systems with standardized, cross-functional transaction automation. (Hendricks, 2007)

- CRM - Customer Relationships Management: CRM systems provide the infrastructure that facilitates long-term relationship building with customers. In particular, CRM integrates system from sales force automation, data warehousing, data mining, decision support and reporting tools. Thanks to this massive data integration firms acquire the ability to manage customer data for different products line. (Hendricks, 2007)

- SCM - Supply Chain Management: supply chain management system allows the planning and the coordination among different supply chain partners. A better planning avoids value destruction resulting in increased revenue and productivity, reduced operational costs and lower inventory. (Hendricks, 2007)

Italy place itself in the European deployment of data and integration in management systems in intermediary position, but with a significant delay with the more

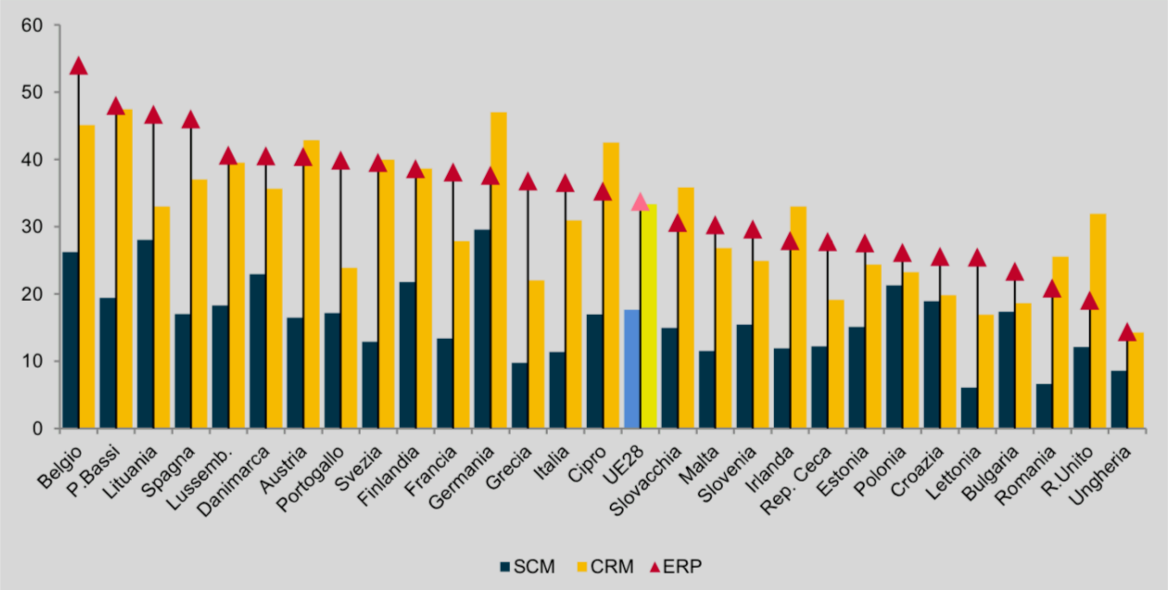


Figure 15: Source Eurostat, ICT usage and eCommerce in Enterprises (Istat, 2018)

1.3.5.2 Impact of "Industria 4.0" plan

First of all, to evaluate the impact of the "Industria 4.0" plan over the Italian industries it useful to analyze which instruments are more appreciated by the entrepreneurial ecosystem

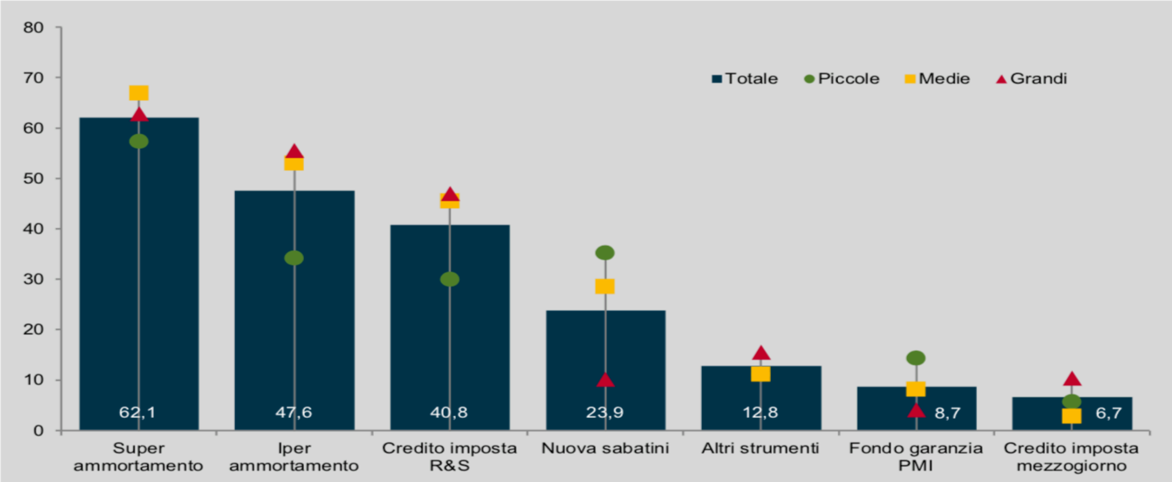


Figure 16 : firms' percentages which repute the incentives "very" or "enough" relevant (Istat, 2018)

shows clearly the incentives that have been mostly appreciated.

- The financial advantages that directly involves the acquisition of new machinery raise major enterprises interests.
- The possibility to purchase at a lower cost equipment is perceived as a greater advantage than other instruments.
- The aggregation of "Iper ammortamento", "Super ammortamento", "Nuova Sabatini" and "Fondo di Garanzia" put in evidence the hostility, despite the figures shown for the "Credito impost R&S", toward investments in R&D.
- All the other instruments have not attracted or convinced the Italian SME entrepreneurs

The analysis proposed by ISTAT confirm a common enterprise trend, return in investment due to R&D require a long-term perspective and more effort to be integrated in the day-by-day processes or in the technology transfer into new products and services. On the other hand, investments in new machinery could bring immediate advantages in terms profit. In prevalence, the required effort regards the process integration.

1.3.6 Updating's of Industria 4.0 proposal in the last Finance Act

The second phase of the "Industria 4.0" plan in Italy has been approved in the most recent Finance act approved in in December 2018 by the Italian Parliament. Although most of the previous plan has been preserved especially with regards to objectives and directives, the form of incentives has been object of review and updates. It follows a summary table which take in consideration the main updating in terms of figures and incentives

Form of Economic incentive	***Updating's***
Iper Ammortamento	Over evaluation of goods purchase increased to 170% for investment until €2,5 million euro, to preserve investments for SME

Super ammortamento	Missing
Competence Center	The creation of the Competence center in line with the European strategic directives of *Research & Competence*, composed by 8 research institute among which: • Polytechnic of Torino • Polytechnic of Milano • University of Bologna.
Credito d'imposta	A restriction towards this instrument has been introduced by the last finance act: • The tax credit falls by 50% to 25% • The maximum amounts of credit for each beneficiary falls by €20 million to €10 million
Nuova Sabatini	The financing participation record an increase with respect to the previous one increasing by 20% to 30%, but only for small dimension enterprise which intends to invest in machinery regarding: 1 • Big data • Cloud computing • Ultra-wideband • cybersecurity • advanced robotics • 4D Manufacturing • Radio frequency identification (RFID)

In addition to the updated version of economic incentive instrument, foreseen by the previous Industria 4.0 Plan, another 2 important incentive that worth to be mentioned, that has been introduced ex-novo with the aim to foster competence enhancing and awareness industry 4.0 concepts as well as to stimulate the labor market:

- *"Voucher for Innovation Manager":* for incurring cost during the period between 2019 and 2020 regarding consulting in innovation technology services the public incentives contribute to a maximum €40.000 until 50% of the cost for small enterprises and a maximum €25.000 until 25% for medium enterprises.
- *"Training Bonus 4.0"*: it consists in a credit tax of 50% for small enterprises and a 40% for medium enterpriser for cost incurred in employee training of topic regards industry 4.0

2 The Digital Twin

2.1 What is the Digital Twin?

In the recent years, the technological innovation brought by the new enthusiast perceptions around the Industry 4.0 concept led the traditional manufacturing system towards a reshaping its pillars. The traditional manufacturing systems are knowing a modernization period due to the facilitated capacity of interconnection among components. Unprecedently, the technological concentration of embed electronics, software, sensors and network connectivity transfers to the so called “things”, the ability to rethink about production processes and organization and their economic benefits. Firms begin to consider new strategical solutions to face the advent of this innovation and how to adapt it and deploy it to extract economic benefits. The possibility to remote control machineries by making setup and monitoring at distance represents an attractive opportunity.

With this premise in mind, it is easily comprehensible the reason why the need of a suitable approach relating to the implementation of new technology could bear considerable return in terms of market positioning. Being an early adopter facilitate the firm future developments and market prosperity.

In this sense, it acquires remarkable visibility a concept that roots its fundamental in the aerospace industry but that, thanks to an accurate restyle finds suitability, indistinctively, across all the manufacturing industry sectors: The Digital Twin.

2.1.1 Which is the exact definition of the Digital Twin?

The first concept of DT can be reconducted to the University of Michigan presentation to industry in 2002 for the formation of a Product Lifecycle Management (PLM) center. As shown in Figure 17 , the slide offered in such presentation detains all the fundamentals of the DT paradigm:

- Virtual Space
- Real Space
- Reciprocal Data flow connection among the two spaces

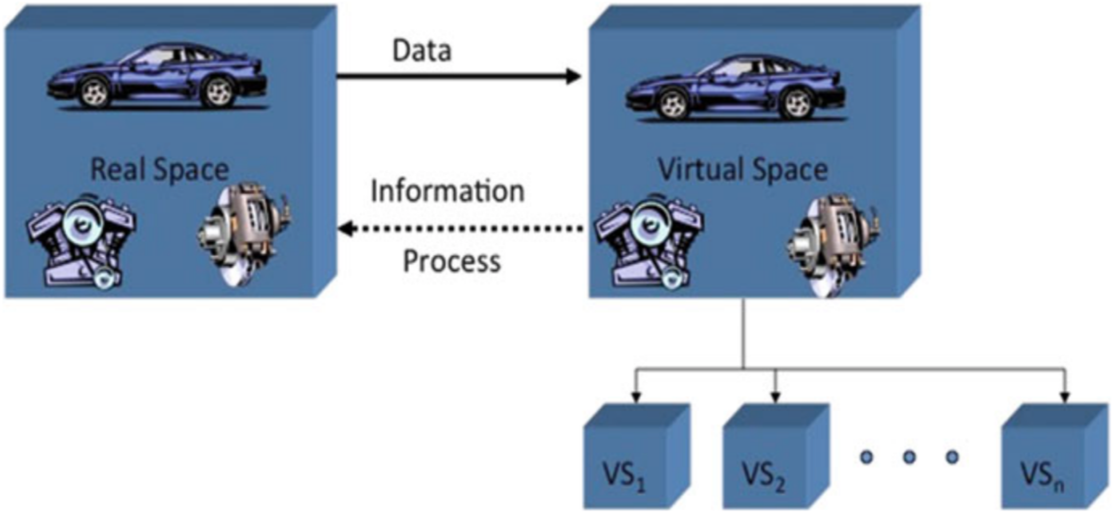


Figure 17 Model of "Conceptual Ideal for PLM"

Despite of the idea of the DT has been introduced in the early phase of the millennium it has been recognized, in literature, that the name of Digital Twin has been already used in the aerospace sector and in particular by NASA in 2010. It has to be kept in consideration that albeit the DT is still looking for shared and approved definition among academic, due to its embryonal development phase.

In this phase a particular focus on the technology is emerged after the spread of the enabling technologies previously described in this section and with greater details in Section 1. It could be historical assumed, in accordance with (Elisa Negria, 2017), that the curiosity and real interest towards the Digital Twin appears, with vehemence, only after the Hannover Messe 2011. It is widely recognized that thanks to the introduction of the Industrie 4.0 terminology in the Hannover Messe 2011, the technologies related to it began to be known in various industries.

It will be offered in this thesis a summary of the main definitions about the digital twin. According to what stated by to (Elisa Negria, 2017) it follows a list of the noteworthy articles related to the definition of the Digital twin assuming that DT acquires an interesting perspective after 2011 considering it with reference to the Indusrty 4.0 concept:

Digital Twin definition	*Reference*	*Years*
"An integrated multi-physics, multi-scale, probabilistic simulation of a vehicle or system that uses the best available physical models, sensor updates, fleet history, etc., to mirror the life of its flying twin. The digital twin is ultra-realistic and may consider one or more important and interdependent vehicle systems. "	(Mike Shafto, 2010)	*2010, 2012*
"A cradle-to-grave model of an aircraft structure's ability to meet mission requirements, including submodels of the electronics, the flight controls, the propulsion system, and other subsystems"	(Tuegel, 2012)	*2012*
"Ultra-realistic, cradle-to-grave computer model of an aircraft structure that is used to assess the aircraft's ability to meet mission requirements "	(Brian T. Gockel, 2012)	*2012*
"Coupled model of the real machine that operates in the cloud platform and simulates the health condition with an integrated knowledge from both data driven analytical algorithms as well as other available physical knowledge "	(Jay Lee E. L.-a., 2013)	*2013*
"Ultra-high-fidelity physical models of the materials and structures that control the life of a vehicle"	(Kenneth Reifsnider, 2013)	*2013*
"Structural model which will include quantitative data of material level characteristics with high sensitivity"	(Prasun K. Majumdar, 2013)	*2013*
"Very realistic models of the process current state and its behavior in interaction with the environment in the real world "	(R. Rosen, 2015)	*2015*

"Product digital counterpart of a physical product"	(José Rìos, 2015)	*2015*
"Ultra-realistic multi-physical computational models associated with each unique aircraft and combined with known flight"	(Brent R Bielefeldt, 2015, September)	*2015*
"High-fidelity structural model that incorporates fatigue damage and presents a fairly complete digital counterpart of the actual structural system of interest"	(Bazilevs, 2015)	*2015*
"Virtual substitutes of real-world objects consisting of virtual representations and communication capabilities making up smart objects acting as intelligent nodes inside the internet of things and services"	(Schluse, 2016)	*2016*
"Digital representation of a real-world object with focus on the object itself "	(Canedo, 2016)	*2016*
"The simulation of the physical object itself to predict future states of the system Virtual representation of a real product in the context of Cyber-Physical Systems"	(Gabor, 2016)	*2016*
"Virtual representation of a real product in the context of Cyber-Physical Systems"	(Schroeder, 2016)	*2016*
"An integrated multi-physics, multi-scale, probabilistic simulation of an as-built system, enabled by Digital Thread, that uses the best available models, sensor information, and input data to mirror and predict activities/performance over the life of its corresponding physical twin"	(Kraft, 2016)	*2016*
"A unified system model that can coordinate architecture, mechanical, electrical, software, verification, and other discipline- specific models across the system lifecycle, federating models in	(Dr. Manas Bajaj, 2016)	*2016*

multiple vendor tools and configuration-controlled repositories”		
“Digital twin is an exact cyber copy of a physical system that truly represents all of its functionalities.”	(Alam, 2017)	*2017*
“The Digital Twin is a set of virtual information constructs that fully describes a potential or actual physical manufactured product from the micro atomic level to the macro geometrical level. At its optimum, any information that could be obtained from inspecting a physical manufactured product can be obtained from its Digital “	(Vickers, 2017)	*2017*
“The idea and concept of digital twin, which is composed of physical product, virtual product, and connected data that ties physical and virtual product, can realize the convergence between product physical and virtual space “	(Tao, 2018)	*2018*

Digging into the definitions proposed it can be elicited the judgement evolution with regards to the Digital Twin. To facilitate the comprehension of such a progression 3 different consequential phase have been identified and analyzed considering the main topic dealt and the extracted consideration related to the technology hype of the period under analysis

1. In the “early phase” the innovative content is focused on the simulation of a real “vehicle”, with a clear association and reminiscence of the aircraft and aerospace industry. The main objective researched in this period showed an attention point towards maintenance of components and machineries by the use of virtual simulation.
2. Thereafter, the attention shifts towards data acquisition due to the increased value perception of data as value added components of product and services enhanced by the Cloud and Big Data analytics technologies pushed in that

years. In this case, the target becomes the data analysis and the potential support in decision making.

3. The last definitions cumulatively combine the previous described aspects inserting a focal point over the interconnection among systems and components. This last topic enlightens the opening towards IoT and the recognition of new business opportunities or new potential market to be explored

2.2 Advantages of Digital Twin by Use Cases

2.2.1 Real Time data acquisition in production system

According to (Uhlemann, 2017) data acquisition requires on average roughly 58% of the time resources, in a range varying between 41% to 74%. An intuitive insight with regards to this data shows that a near real time continuous acquisition through sensors, brought by Digital Twin solutions, could remarkably simplify a time-consuming process, in addition to the reduced possibility of human manual mistakes.

Within this context 3 different Digital Twin components deserve to be mentioned according to:

- *Data acquisition*

  Digital twin solutions enable the capture of two type of data that needs to be distinguished: volatile and non-volatile.

1. The first employ the real time locating system and image processing, enabled by wireless systems constituted by the interconnection of sensors and anchors. These technologies allow to record movement and times of machineries following the production flow and the machinery capacity

   The second deal with data detects by measurement and interviews of specifications of machinery and BOM (bills of materials)

- *Data Warehousing*

  The Cloud solutions foreseen by the Digital Twin model enable, through the development of an ad-hoc interface between the interconnected production systems and the Cloud, the possibility to have well performed data storage more resilient and virtually unlimited.

- *Data analysis*

  Thanks to the gathered and stored data, a new dimension of analysis can be explored. The Digital Twin solutions include the use of advanced algorithms, e.g. artificial neuronal networks for machine vision, and optimization methods which foster the production monitoring and efficiency

2.2.2 Predictive maintenance

Thanks to the constant and continuous ability to acquire data from low cost sensors and digitalized equipment, a new frontier in the monitoring approach push company to think about innovative solutions in terms of maintenance. A predictive approach is suggested by the solution Predix APM (Asset Performance Management) proposed by GE. This innovative SaaS offers 3 clouds modules:

- The first module which evaluate the possibility to monitor the health of the asset. In this sense the operational data collected are presented in ad-hoc report that involves the use of appropriate metrics and alerts and signaling system
- A second module: integrates the workers devices by collecting all data acquired by each single worker and advising him, in real time, about the emergence of issues with suggested resolution and complementary essential information.
- A third module involve a calibration system that with ad hoc user interface allow the remote control of machineries and sensors supported by the suggestion of calibration of instrumentation and critical plant devices. In such a way an optimized and improved performance of instrument enable optimal planning and a considerable advantage in the industrial strategy.

According to General Electric figures a quantitative end-to-end value can be assumed to be reliable:

1. 2 - 6% increased availability of instruments
2. 10 - 40% reduction in reactive maintenance
3. 5 - 25% gain in employment productivity

2.2.3 PLM Digital Twin applications

A crucial aspect in the product design and realization is the planning phase of the product lifecycle. The product lifecycle management concern the process of conceptualization, design, procurement, manufacturing to use and recycle of the product. As it can be seen in Figure 18 each PLM phase involves an extensive data generation. Nowadays according to (Tao, 2018) it resembles that data gathered during each phase of the PLM are stagnant, isolated and fragmented. Data are not complementary in each phase of PLM, interoperability among systems and the data structure is not assured. The data integration and the interaction between systems it is considered by the most the new main asset over which leverage new value creation. Another crucial gap still existing in the PLM regards the distance between the physical and the virtual dimension of the product. The actual PLM research focuses on the physical product rather than on the virtual one. Furthermore, the keeping track of the actual demand and immediately reshape design and manufacturing of new products still remain an obstacle in the PLM.

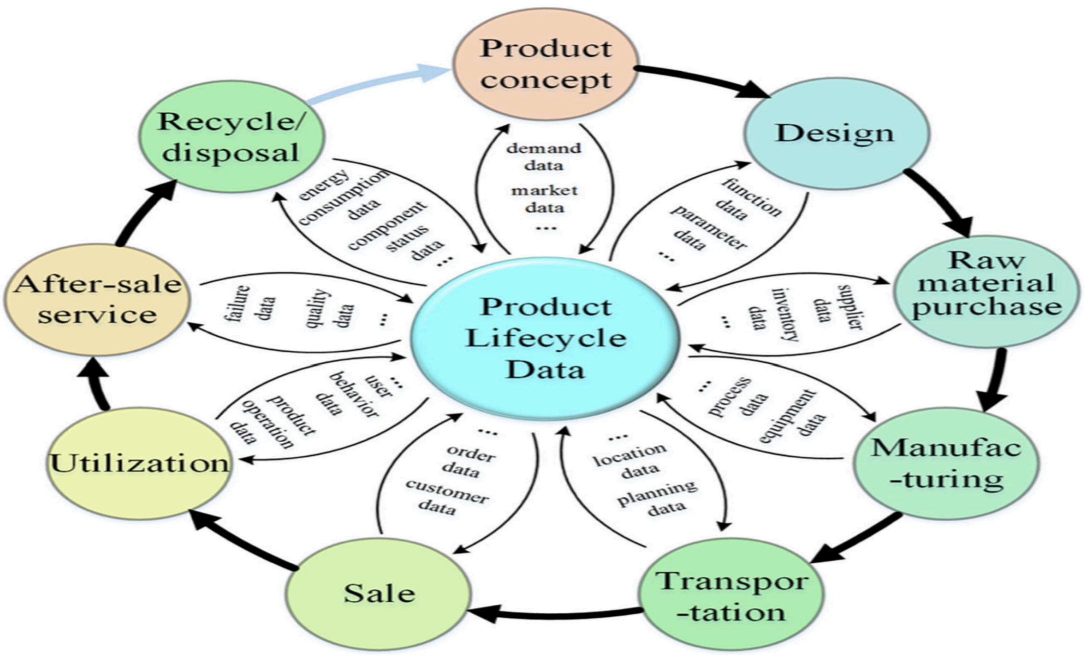


Figure 18: Product lifecycle phases data scheme, source (Tao, 2018)

The Digital Twin intervene in the PLM as a possible solution with the intention to address the topics discussed in this section. But in which context of the PLM the Digital Twin can be influent?

1. Digital Twin in product design:
   The focus on the design phase of the product lifecycle involve the application of the digital twin in 3 distinctive phases according to (Tao, 2018)

   - *Conceptual Design:* is the first step of the product design phase and deals with the idealization of the aesthetics features and the main function of the product. The Digital Twin offers support to designers in collecting and presenting all data needed to implement the desired features requested by the market through the integration of customer satisfaction, product sales, product competitiveness, investment plans, and many other data. In addition, another crucial aspect regards the communication between the customers and client. The match of the desired product with the customer requirements is reinforced by real time exchange of information which facilitate product development refinement and a rapid time to market. The customer could participate to the design conceptualization phase enhancing his/her final satisfaction and reducing time and material consumption
   - *Detailed Design:* thereafter the concept designs the designers has to complete product prototype and the development of the necessary tools and equipment and begin with the test phase. The Digital Twin offers advantageous aspects in the test phase, thanks to simulation environment proposed it enables product configuration and parameters tuning as well as by offering an accurate storage of historical data that avoid configuration repetition and optimize the source of possible new test.
   - *Virtual Verification:* the last phase of product design usually foresees the validation of the test executed by pushing in production a small batch of product that can be eligible to validate what has been achieved until that moment. Often this approach requires repetition of small batch production lengthening the time to market and wasting material, machine time and labor time. Thanks to the digital twin this last design phase can be

transferred to a simulation performances environment which ensure to predict the potential performances of the design achieved.

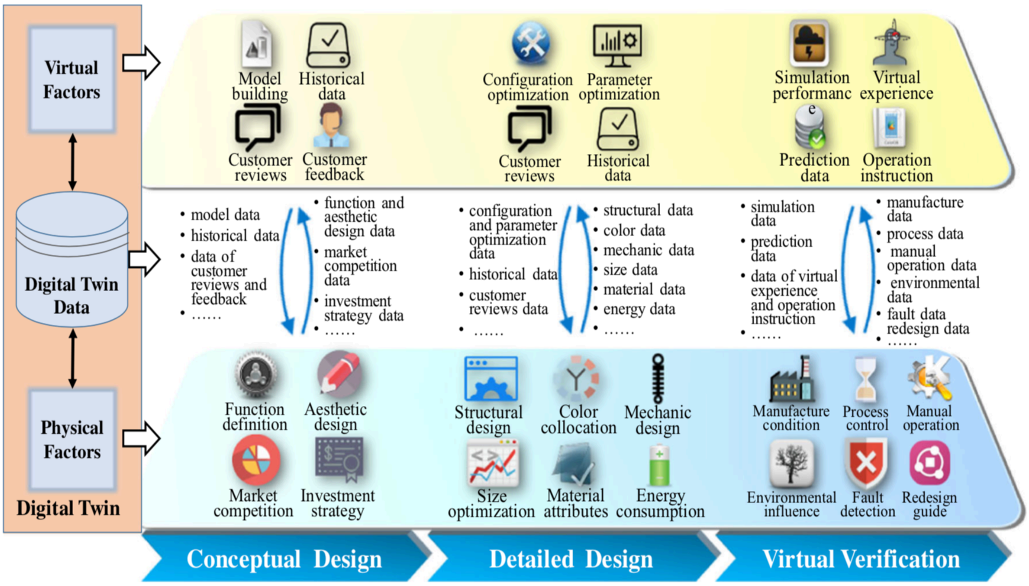


Figure 19: Digital twin-based product design, source (Tao, 2018)

2. Digital Twin product manufacturing:

   the product manufacturing entails each phase able to transform a raw material in a finished product. To sum up the main activities involved in this process can be cited:

   - resource management
   - production plan
   - process control

To foster each activity a well-organized structure, empower the correct fulfilment of the entire product manufacturing. The Digital Twin solution, according to (Tao, 2018) proposed a structure called DTS, Digital Twin Shop Floor. This structure combines three dimension that follow the entire manufacturing procedures for each activity previously described, by the integration of Physical Space, the PS “Physical Shop Floor”, a pure Virtual information space, the VS “Virtual Shop Floor” and an interconnection space of the last two, the SSS “Shop floor Service System”, converge. The nature of the convergence determines the added value of this model which is enabled by its constituent the SDTD “Shop Floor Digital Twin Data”.

The tasks to be executed, foreseen by the production plan, are simulated in the VS where optimization algorithm process data coming from PS. The results of optimization are further processed by the integrated software systems, such as MES, PLM, ERP, CRM and each other management software at disposal of the SSS, where resource management and process control optimize with attention the data provided. The execution tasks are communicated to PS to be executed. The iterative production process aims to be guarantee process control and maximization of the production capacity by the deployment of Real time data

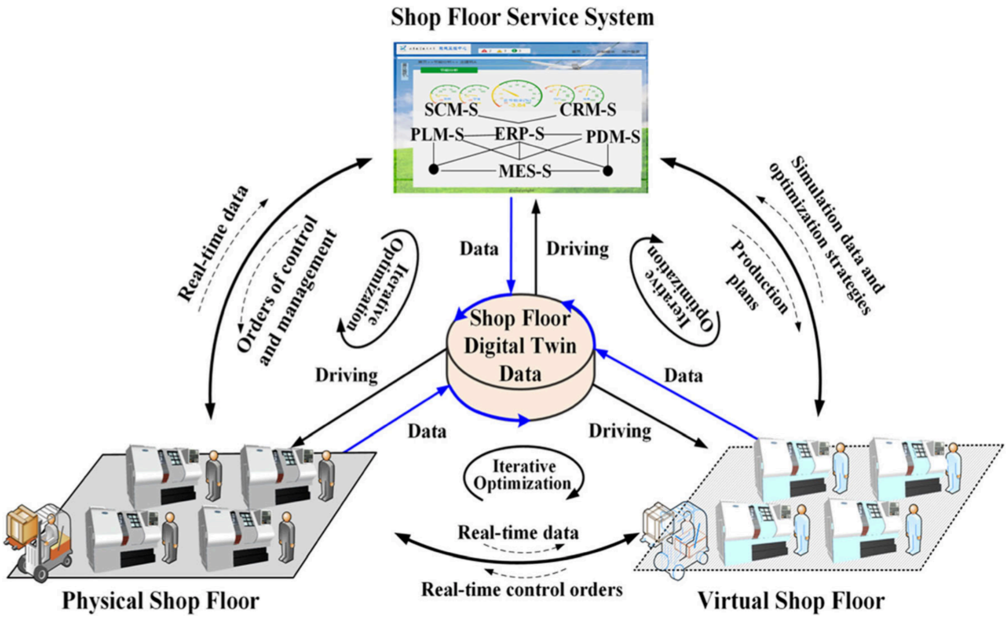


Figure 20: composition and operations mechanism of DTS, source (Tao, 2018)

A practical example of DTS is offered in

Figure 21 with regards to the production of steel bars. The RFID tags on the bars allow the bars tracking which can be elaborated by CNC machine. The CNC machines are connected through the enterprise network and can continuously transmit real time production data. The data received can be processed and simulated by the VS, which starts optimization. The integration with SSS supported by the information systems (ERP, MES, PLM) allows an enhanced process control and support for the operator in taking equipment decision or machine production plan.

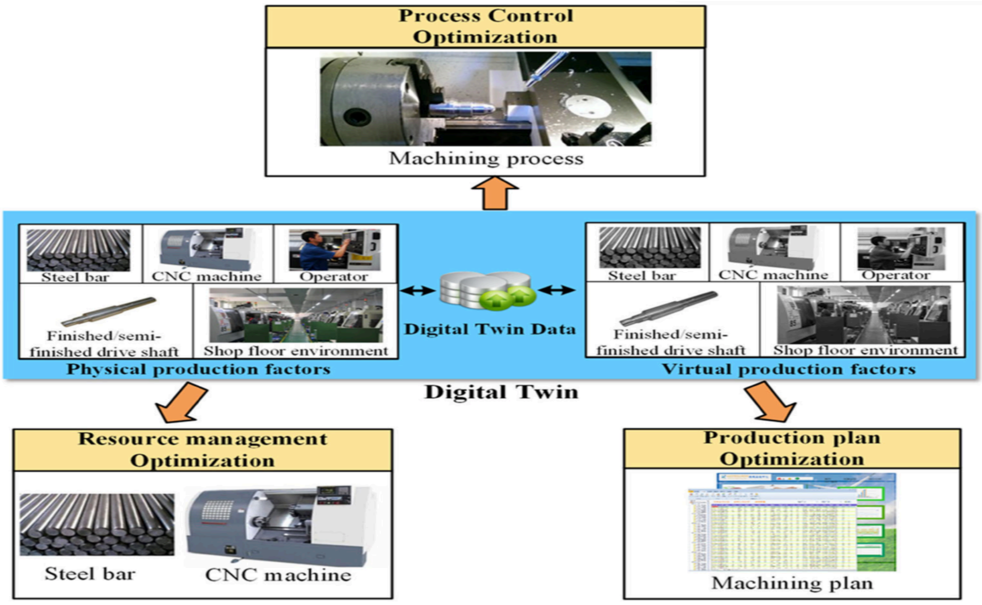


Figure 21: The drive shaft manufacturing based on digital twin, source (Tao, 2018)

3. Digital Twin product service:

   A further implementation in the product lifecycle refers to the after-sale services. In Figure 22, it is proposed by (Tao, 2018) a summarized version of potential services enabled by the Digital Twin solutions. The main groups of after sales services can be grouped in:

   - User support: management of user's behavior data reinforced by analysis, allow new potential service in user's monitoring and creation of operations guide. This last topic is empowered by the real time data elaboration, as matter of fact operative suggestion to operators, could be seen as a crucial aspect not only for production but also for operator's security
   - Maintenance and product failure
   - Optimization of productive systems
   - Energy consumption and savings

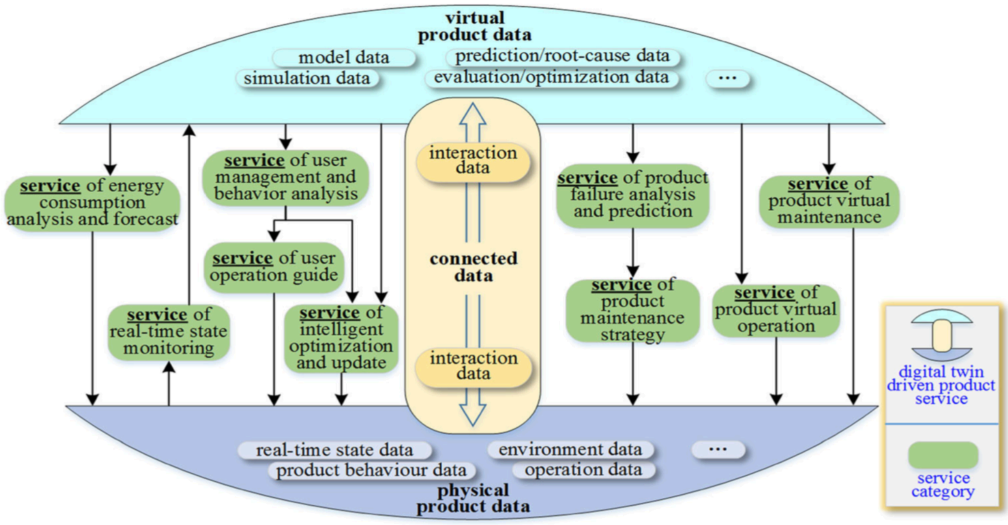


Figure 22: Digital twin-driven product service, source (Tao, 2018)

2.2.4 Digital Twin and the additive manufacturing

Additive manufacturing, as described in 1.3.4 , it is still a costly manufacturing process, due to its the high degree of novelty, especially with regards to time-consuming physical experiments. The Digital Twin within this context bring remarkable advantages due to its high capacity of simulation, in this case with reference to numerical and computational experiment. The new generation of additive manufacturing Digital Twin according to (Knapp, 2017) should foresee a building block made by a computational efficiency which can assure prediction with regards to:

- Deposit geometry
- Transient temperature
- Velocity distribution and solidification parameters in three dimensions

2.3 Digital Twin Business Model evolution

An important question related to the introduction of the Digital Twin technology is: how a business model can be built over it?

To address this question, it can be possible to begin by the analysis of the potential use case emerged in section 2.2. The Digital twin affection over the value chain hits different layers of the model proposed by (Porter, 1985), with particular reference to

manufacturing and operation of the day by day and technology improvement. Yet, the layer which is subject of a greater impact and that deserves to be mentioned is the new profitable perspective that acquire the provision of services.
The service is the core elements of the Digital Twin business model. The majority of the use cases previously analyzed, thanks to the support of the Cloud technologies as defined in section are enabled by the provision of PaaS 1.3.4.
As matter of fact, the high level of the Digital Twin modularity opens to new opportunity of business based on a platform product model (Marco Cantamessa, 2016). Customer can benefit from on demand services by having guaranteed the most recent version of technology without incurring in sunk cost. To support this assumption, it can be considered a practical use case: the predictive maintenance over equipment offered by digital twin solution bring noteworthy advantage to customer and can be offered as SaaS module by machinery suppliers. Contemporary, customers can utilize the service on demand, according to their exigencies, outsourcing the entire process, lightening operational staff allocated on the maintenance tasks and reducing costs.
Another Digital twin business model opportunity concern an innovative approach by considering in-service data gathered during the continuous real time data acquisition (Veronica Martinez, Novembre 2018). The data gathered begin to constitute a new source of value deployable in new form of services and related business model.
By research in literature the Digital Twin can be classifiable as Product Service System, according to (Tischner U, 2002) a "tangible products and intangible services designed and combined so that they jointly are capable of fulfilling specific customer needs"
For such a reason the creation of new services enabled by in-service data generates different possible business model that can be for simplicity grouped in 3 categories with reference to the business models foreseen in the theory proposed by (Tukker,

2004):

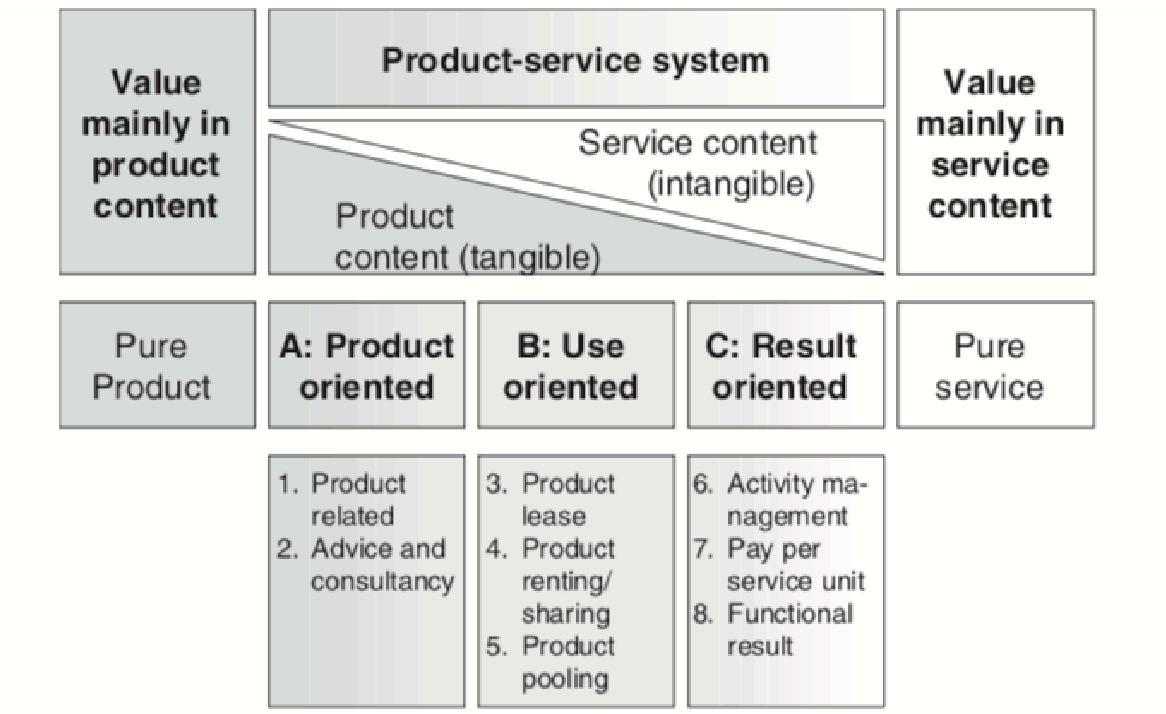


Figure 23: Subcategories of Pss, source (Tukker, 2004)

- *Simple services:* looking at Figure 23 the Tukker classification simple services corresponds to advice and consultancy based on Digital Twin data or even monitoring activities due to real time information, hence classifiable as Product oriented service.
- *Advanced services:* looking at Figure 23 the Tukker classification the advanced services refer to the optimization of the production system by the use of in-service data of assets. Predictive maintenance cited before falls under this category. A revolutionary approach with regards to this section needs to be mentioned, the involvement of supplier shifts one of the components of the value chain towards a virtual vertical integration. Suppliers begin to support asset's operators and to assisting their decision by provisioning useful data. This category can be classified as Use-oriented services.
- *Result oriented services:* looking at Figure 23 the Tukker classification the result-oriented services refer to pay per use service and functional results. The Digital Twin technology enable an innovative business model approach considering development of new pricing schemes for suppliers. Traditionally, suppliers and client base the pricing system on one-shot transactional pricing. Instead, with the

Digital Twin, services prices could be quantitively determined in functions to the real use and/or pre-determined by results-oriented algorithms. In addition, a further pricing model based on subscription systems for the services and pay per use systems for the product can be introduced within this context.

2.4 Digital Twin solution in the world

In the recent years the Digital Twin have been experimented across a considerable amount of industries without distinction regarding dimension. As matter of fact, both corporations, large firms and SME have tried to exploit the potential advantages of DT. In this section it will be presented a series of use case application of DT to point out the methodologies and solutions adopted in different circumstances

2.4.1 Digital Twin in Large company

Digital Twin in large companies have found different understandings thanks to the analysis of industrial practices. According to (Benjamin Schleich, 2017) it can notice that:

2.4.1.1 General Electric digital twin products:

General electric Digital Twin solutions focus its attention over forecasting the health and the performance of their products over lifetime. The three modules proposed to customers are addressed to provide a specific service:

- Predix Asset Performance Management: as previously mentioned in section 2.2.2 the focal point it is over maintenance and monitoring asset health avoiding to incur in time waste of any sort and consequently benefit of increased production and reduction of cost.
- Predix Operations Performance Management: this module deploys performances optimization algorithms aiming to enhance plant's throughput as well as ensuring operations quality and efficiency by:
    - Maximizing productivity
    - Accelerating time to value
    - Support operational decision

- Service Max: module dedicated to operator's time and tasks management thanks to interconnection with the data coming from production system. The client satisfaction of this software tool could derive from an increase of the operator productivity by the provision of simple services:
  - Scheduling activities
  - Monitor daily activity and performances of operators
  - Capture and deliver the suitable performance metrics in function of the actual machine results

2.4.1.2 Siemens digital Twin products:

Siemens digital solutions focalize its attention on improving efficiency and quality manufacturing digitalization in the context of Industry 4.0 and the PLM. As a matter of fact, Siemens declares PLM's view of the digital twin is primarily around creating digital models that can accurately predict the behavior of products. In fact, Siemens has a vision for multiple digital twins, for example to allow companies to simulate a product being manufactured on a virtual twin of the product line that creates it.
In addition, virtual twins of product allow simulation using actual control software code on virtual PLCs to validate production automation at each step with a "software in the loop" approach and virtual commissioning.

The Siemens offer span from CAE tools, design tools, mechanical CAD tools, which helps to design product to manufacturing tools, shop floors, ALM (application lifecycle management).
The scope of the Siemens product includes various aspect such as (Dave Riemer, 2017)

- Product simulations
- Plant simulations
- Manufacturing process simulations
- Maintenance simulations

2.4.1.3 Tesla digital Twin products:

Tesla Motors is deeply investing in digital twin technology as a way to provide better service and reliability for Tesla owners. The Digital twin application refers to the creation of a digital twin version of each car produced as a follow up process in the after-sale phase of the Product Lifecycle.

Tesla then updates software based on individual vehicles' sensor data and uploads updates to its products. This data-driven software development process enables more efficient resource allocation and a markedly better user experience for the vehicle owner.

2.4.1.4 Dassault Systèmes digital Twin products:

Dassault Systèmes look at the Digital Twin as a link between the physical and the virtual Space on a single platform involving different modules in support to designers to virtually build and interact with complex systems. (Grieves, 2019)

The target of the platform proposed by Dassault, is on the product design. To ensure its development a collaborative approach among different business divisions can contributes to a reduced time to market of the product and a reduction of cost and time. The parallelization tasks enabled by the product design over a uniformed platform offer remarkable interoperability benefits that business functions, from engineering, marketing and operations can take advantage of.

2.4.1.5 The Digital Twin for IoT: Bosh IoT

Among the various Digital Twin application available, on in particular deserve honor to be mentioned because of its high innovative contents. As matter of fact the Bosch IoT solution proposed a Digital Twin version for IoT. As presented in (Christian Friedow, 2018, June) the integration of IoT in business processes it is enabled by the use of Digital Twin solutions. For each connected device on the network of the IoT it is associate a "Twin" which has its own representation in the Cloud reflecting the value of the physical devices attributed to the mapped related variable. A common mapped variable regards the geolocation measured by the continuous recordings latitude and longitude data acquired by sensors in case of location change.

In substance for IoT the Digital Twin intends to fill the gap between physical sensors and a front-end visualization and representation of the twin. Digital Twin in this context offer a cloud service and a platform over which to develop further services. The possibility to simulate multiple virtual node on the basis of the one already mapped offer opportunity to test potential connected devices networked capacity and reliability as well as ensuring the communication among each other. The twins altogether constitute a distributed network over which the Digital Twin has to assure the interoperability

3 Focus on SME of the Piemonte region: Digital Twin business requirements research - Survey

3.1.1 Analysis Objective

The objective of the analysis is to define the attractiveness as well as business and technical requirements for the development of the Digital Twin. In this context the Digital Twin refers to the Italian SME manufacturing, in particular the one present in Piemonte region. The market research has been conducted during the stage activity proposed by the Istituto Mario Boella in collaboration with the researchers of the ICE@Lab of the Polytechnic of Turin.

The principal aspects posed under evaluation regarded the instruments and the possibilities offered by the Industry 4.0., and the level of readiness of firms about it.

The Industry 4.0 technologies knowledge have been object of scrutiny with focus on:

- Effective implementation state
- Desired benefits
- Firm’s activities impacted by the use of such technologies

The investigation has kept in consideration the Industry 4.0 incentives and its payback return.

Speaking about Digital Twin it can be easily noticeable the tight connection to the Cloud technology, which allow to employ the potential of data storage to effectuate data analysis and enable data ubiquity, accessible by whatever device.

For this reason, an important section of the survey was dedicated to investigating the degree of implementation of cloud solutions, but above all the willingness of companies to share data on servers not directly managed in the company. At the end of the company classification phase, we proceeded to determine the knowledge of the Digital Twin technology, propose a series of possible implementations based on both the current state of the art and the analysis of the literature in this regard and finally assess the availability to make these investments together with the expected payback period of the same.

3.2 Survey approach

The survey method adapted is the de-visu interviews conducted by two interns, one of whom was only responsible for collecting the answers received to keep track of the of it in the meanwhile the other intern conducted the interview in form of discussion rather than in case of mere questionnaire. This last point potentially enhances the quality of the results because a greater sensibility in the answer interpretation and because rapid clarification in occurrence of misunderstandings. In cases where the entrepreneurs have expressed their willingness to be interviewed, it was decided to directly collect their answers, with the support of other technical devices, in order to obtain answers as truthful as possible.

3.3 Survey structure

The interviews were based on a questionnaire built ad hoc to be used as script for the questions to be asked by the interviewer.
The questionnaire, hosted by the LimeSurvey platform of the Polytechnic di Torino and developed by an accurate selection and mixture of previous submitted questionnaire and brand new built to fit questions, is characterized by an introductory part: which provides the description of subjects offered in the interview
It follows the description of the sections that compose the questionnaire:

1. Firm’s interviewed identification
2. Implementation degree of Industry 4.0 high-tech solutions in the SME context
3. Degree of knowledge regards to Industry 4.0 concept in SME context
4. Assessment regards to the state of knowledge regards the Digital Twin paradigm for Industry 4.0
5. Firm’s respondent contact details to be contacted for further inquiries or for sharing information.

3.3.1 Firm’s interviewed identification

In the first section a collection of a series of generic and anagraphical data are requested in order to get the company’ details and its reference market, in particular:

- Firm brand name
- Role in the firm of the interviewed
- Industry in which the firm operates
- Firm's Activity
- Number of employees in the firm
- Served markets by the firm
- Foundation year
- Revenue
- Market share

Thanks to the information gathering described the focus on the market segments of interests become easy to be interpreted.

Subsequently, the question asked to begin to regard the management of the Supply Chain distinguishing from the customer and supplier side. The questions aimed to comprehend

- the number of the firm's suppliers
- in case the firm has one or more main customers and if so, how much percentage of the turnover depends on these.

The section conclusion foresaw some questions addressed to the production area. The intention concerned

- To understand the presence of peaks and / or seasonality
- The solutions adopted by the firms in case of peaks and / or seasonality

3.3.2 Implementation degree of Industry 4.0 high-tech solutions in the SME context

In the second section the point of attention shifts to the assessment of Industry 4.0 paradigm and the technologies connected to its knowledge. Furtherly, it is asked about the awareness of the available forms of economic incentives for technological development the Industria 4.0 plan (to insert the cross reference). Subsequently, a series of questions asked to investigate the relationship of the company with the data involved in its production activities or those related to the firm's suppliers /

customers. Thereafter, a proposed set of questions regard the GDPR regulations has been made, in particular the focus went to:

- Analysis of the actual knowledge degree regards the topic
- In case of positive response: the actions taken in response to the introduction of the new regulation.

Another aspects object of investigation through a dedicated set of questions regards data property and management, in particular:

- Firm willingness to share data: with attention on technological storage instrument used (e.g.: The Cloud)
- The firm perception with regards to the threat brought by Cybersecurity
- The firm actions taken to contrast the risk of Cybersecurity: with focal point to the degree of knowledge in cybersecurity and what security techniques are used in the company.

In conclusion, a point of attention is directed to the utilization of Cloud solutions and the perception of security of a cloud storage service compared to internal data storage conservation.

3.3.3 Degree of knowledge regards to Industry 4.0 concepts in SME context

To analyze the degree of knowledge of the assimilated concepts of Industry 4.0 for SME the third section has been structured in order to investigate the important activities SME consider relevant to conduct their businesses. It has been provided to the interviewed person a list of activities with the multiple choice's logic, as follow:

- Small lots customization to be produced
- Production process automation
- Reduction of energy consumption
- Business sustainability: with concern to environmental impacts
- New generation maintenance services: preventive and predictive one
- Vertical integration
- Horizontal integration

- Firms ability to respond in occurrence of changes and organizational flexibility
- The use of collaborative robotics: recognized under the name of COBOT
- Attract high specialized resources in mechatronics, electronics and computer science and automatic control
- Process analysis and monitoring through data collection
- Predisposition to offer services in addition and / or in support to physical products
- R&D activities
- Planification of employee trainings about new digital tools
- Introduction and use virtual simulation environment and product design software
- Definition of formal innovation plan with strategic approach
- Willingness to introduce innovation managers or managers dedicate to the digitalization process

The last set of questions aim to obtain a coherent answer for the subsequent question, in a certain sense their positioning is intended to be preparatory.

Further, to get a deeper insight about the qualitative purposes desired by the adoption of the Industry 4.0 technologies, another set of question has been proposed. The declared goal it to put under scrutiny the recognized benefits from the technologies adopted as-is and the expected benefits foreseen by adoption of certain technologies in the future, to be. Even in this case the answers are selected on the basis of a multiple-choice list:

- Increase of efficiency
- Increased productivity
- Cost reduction
- Increased transparency in the activities carried out by the various players in the supply chain
- Interoperability between the various actors, synchronization and exchange of information
- Improvement in decision-making
- Reduction of timing (e.g. time-to-market, set-up)

- Increase in profits
- Increase in the quality of products / processes
- Increase in reliability of products / processes
- Creation of customized products in small batches
- Increasing worker safety
- Leveling of energy loads and reduction of energy use
- Greater consumer satisfaction
- Improvement of the product life cycle control process

A last question with dual function:

- aims to understand if the firm previse a strategic plan with the goal of innovation fostering
- as verification and validation of the previous responses with regards to the same topic

3.3.4 Assessment regards to the state of knowledge regards the Digital Twin paradigm for Industry 4.0

In section four is present the core of the survey. The analysis of the business development requirements regard to the Digital Twin are hosted in this section, the section structure foresees a synthetic academic description of the Digital Twin technology, whose function is to support the oral presentation of the interviewer, followed by a question that investigates the previous knowledge with regard to the cited technology.

Thereafter, a further question is asked: without mentioning the specific technology it is investigated, if some of the potential features and opportunities proposed by the Digital Twin, are matter of interest for the enterprise's business. If the response gives back positive feedback the investigation goes deeper with the proposal of a list of possible implementations for SMEs in order to assess the degree of utility for the entrepreneur:

- Real-time information on the status of the machinery or the entire production line

- Real-time information on the activities carried out by employees
- Data collected in the cloud and accessible from any computer connected to the network and possibly from smartphones
- Ability to exploit data collected in real time to perform mathematical-statistical simulations on production processes in order to make production and resources more efficient
- Share some of the information collected with its suppliers in order to better schedule their production activities
- Automatically share some of the information collected with your customers
- Possibility to register and certify in an automatic / semi-automatic way all the processes or activities necessary for production and possibly provided for by the contract
- Possibility of receiving automatic suggestions and indications regarding the compliance of processes / processes with respect to ISO standards in the sector
- Predictive analysis, on the data collected, aimed at signaling the future date of machinery failure
- Predictive analysis, on the collected data, aimed at indicating the impossibility of delivering a contract in time

In addition, further final questions are submitted about the entrepreneur's willingness to invest in the Digital Twin technology. To support this last investigation has been offered a reminder to the benefits obtained by the investment in Industry 4.0 made in the past and the identification of the average expected return of the investment period.

3.3.5 Firm's respondent contact details to be contacted for further inquiries or for sharing information.

At the bottom of the questionnaire a last part is dedicated to entrepreneurs contact details with the aim to get in touch with entrepreneur to:

- Submit new future interviews
- Offer the research results obtained
- Notification or invitation to Industry 4.0 events

3.4 Scales methodologies

The questionnaire presents four different types of questions:

1. Direct positive or negative answer: single-answer
2. Multiple choices questions
3. Open question: the interviewer could give back extensive answer regard to it
4. Likert-based questions: Regarding the Likert scales, these were used in 4 questions (multi-item). The introduction of this scale aims to the evaluation of answers in terms of average distribution for the topic investigated.
   The scale levels have been accurately selected as follow:
   - Questions regard the knowledge of the technologies of Industry 4.0: the choice fell on 5 levels
     - Very Low
     - Low
     - Medium
     - High
     - Very High

     In this manner there exist the possibility to express a neutral position considering the extremely innovative and technical topic discussed
   - Evaluation of the development requirements of the Digital Twin follows what defined for the question above
   - Question regard the implementations of Industry 4.0: the scale changes in this case and it has been based on 4 levels,
     - Not of interest
     - Of interest but not yet implemented
     - Present in the plan
     - Implemented

     The scale changes because of the need to force the interviewed to give a non-neutral and consistent answer.

     The conversion adopted in the statistical software is mapped as follow:
     - 5 levels scale: 1-2-3-4-5
     - 4 levels scale: 1-2-3-4

3.5 Sample selection

The sample selection required the preliminary planning in collaboration with ISB and ICE Lab director and researchers. The assumptions over which the sample has been constructed kept in consideration:

- The distinctive characteristic of the Piemonte region, traditionally high-level productivity
- The technology under investigation
- Industrial applications opportunities

The decision taken concern the investigation of the manufacturing sector of SME or in production areas in which the prevailing activity deals with production and processing of physical products. Particular attention, even without neglecting any sector, has been placed in the preference of engineering companies, given the vocation of the territory to the automotive and aerospace industries. We tried to replicate a sample of interviews that reflected in the most faithful way possible the fabric of Piedmonts SMEs.
Given the type of face-to-face survey and the limited time of training, the number of companies interviewed was 20 in number.

3.5.1 Modality of enterprise contacts details gathering

The activity of research of enterprises contacts details occupies half of the stage time. Due to the meticulous selection of the sample it has been necessary to interrogate several Database. Among the sources of information used can be cited:

- The collection of companies that have hosted management engineering interns over the past few years
- Companies exhibiting at the A & T fair in Turin
- The collection of innovative SMEs provided by the Chamber of Commerce
- MESAP associates and contacts from CDO and CNA Torino

Some criteria have been determined to refine the selection of the company and focus on the target desired:

- The firm industry segment of influence
- The firm turnover and the number of employees

An activity of emails sending which entails roughly 150 emails has been conducted. The response rate obtained of 15% of which only 10% ended positively with interviews. To hit the target of 20 interviews the email body is dynamically changed and refined in order to better perform in terms of response rate. Effectively, thanks to the email text improvement

we reached the final version of the email that guaranteed a positive response in 2-3 cases out of 10.

3.6 Results

3.6.1 Industry overview: focus on firms

The analysis of the data showed that the sector most represented in the survey is the engineering industry, with 75% of the responses to which a 5% of the automotive is added, always in the field of mechanical processing. The remaining 20% is made up of the chemical and electronic sector, as can be clearly seen in Figure 24

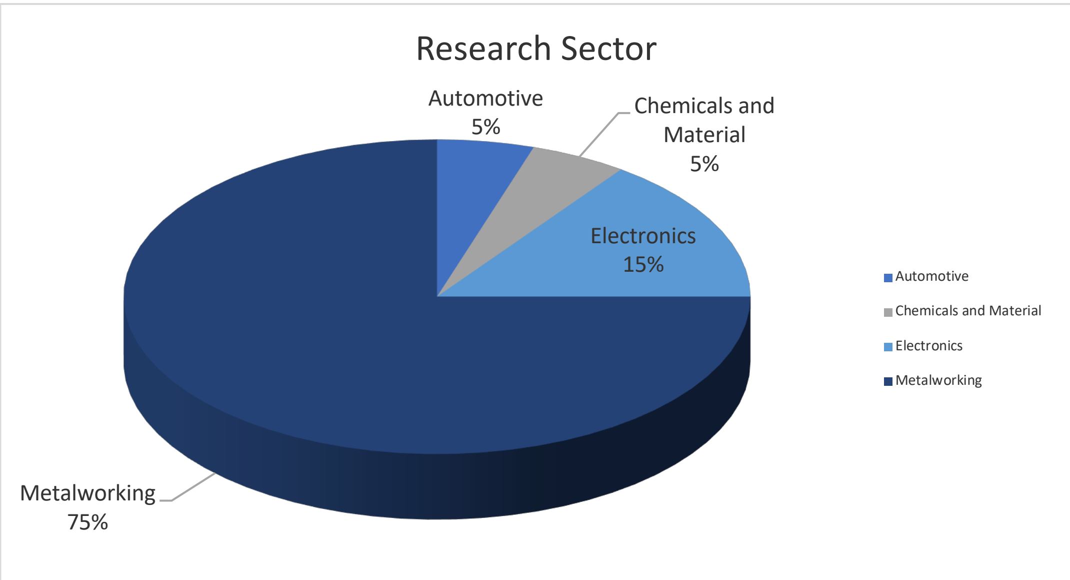


Figure 24: Research market segmentation

The 80% of the sample is composed by the owner of the company, considering also the senior management figures we reach a quota of 85%. This data enriches the value of the sample responses because of the interest of the research to have an insight about the entrepreneur's attitude towards investments in innovation.

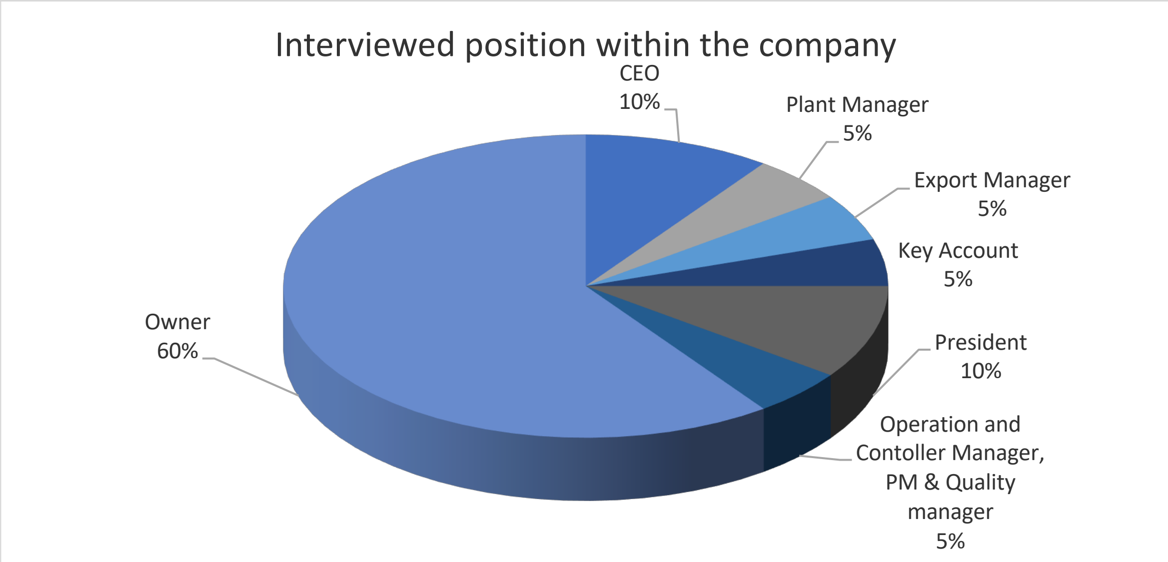


Figure 25 Interviewed position within the firm

By considering the internationality of the interviewed sample, the investigation produced the following results: 30% of the respondent companies has only national market, while 70% they serve both national and international. It has to be evidence and emphasized that entrepreneurs interviewed express preference to export with the clear intention to serve foreign market. This attitude roots itself in the demand stability and requests for orders but most of all the certainty of payments. Generally, considering foreign markets are considered even more profitable.

In 99% of the cases the commercial activities relate to requests on orders, a figure in line with the selection of the sample selection.

An additional information analyzed through the data collection gained during the submission of the survey regards the company foundation year. The response is reported in Figure 26, three main groups can be identified:

- Historical companies: belong to this group the companies with a foundation year that goes from 1938 to 1959, this aggregation results in 6 companies

- Light Historical companies: belong to this group the companies with a foundation year that goes from 1971 to 1988, this aggregation results in 7
- Recent companies: belong to this group the companies with a foundation year that goes from 1994 to 2016, this aggregation results in 7 companies

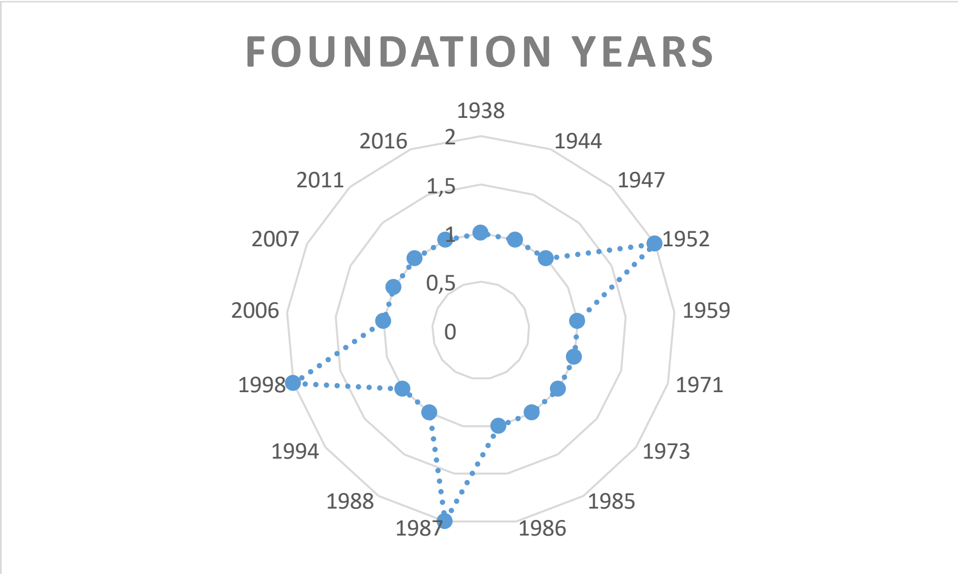


Figure 26: Foundations years of the companies interviewed

As mentioned in the description of the surveys the data regarding the turnover and the number of the firms employees are taken as index to select the companies that compose the sample, As result of the selection mad roughly 90% of the sample are small businesses, considering the employees amount less than 50 people and the turnover inferior to 10 million euros .The remaining 10% is considered of medium-size companies with the employees amount inferior than 250 people and the turnover inferior to 50 million euros

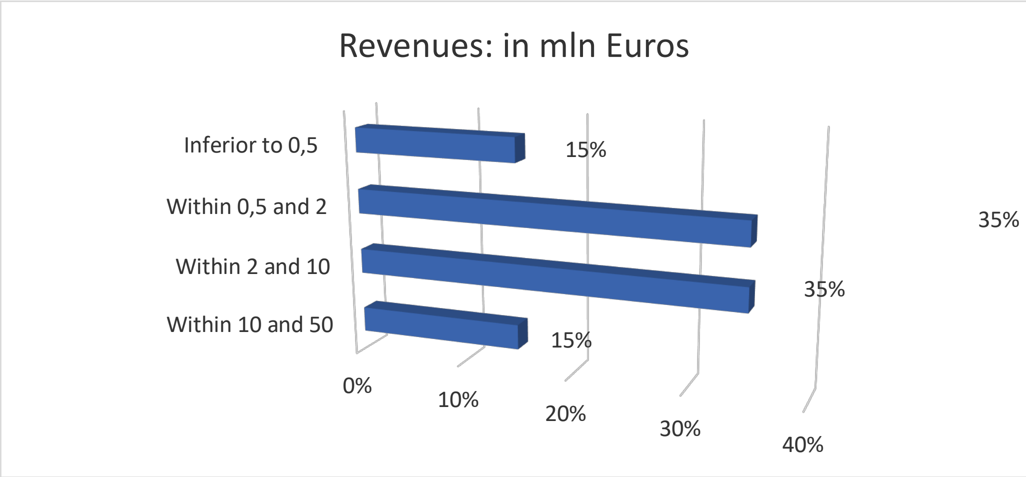


Figure 27 Interviewed firms' revenues

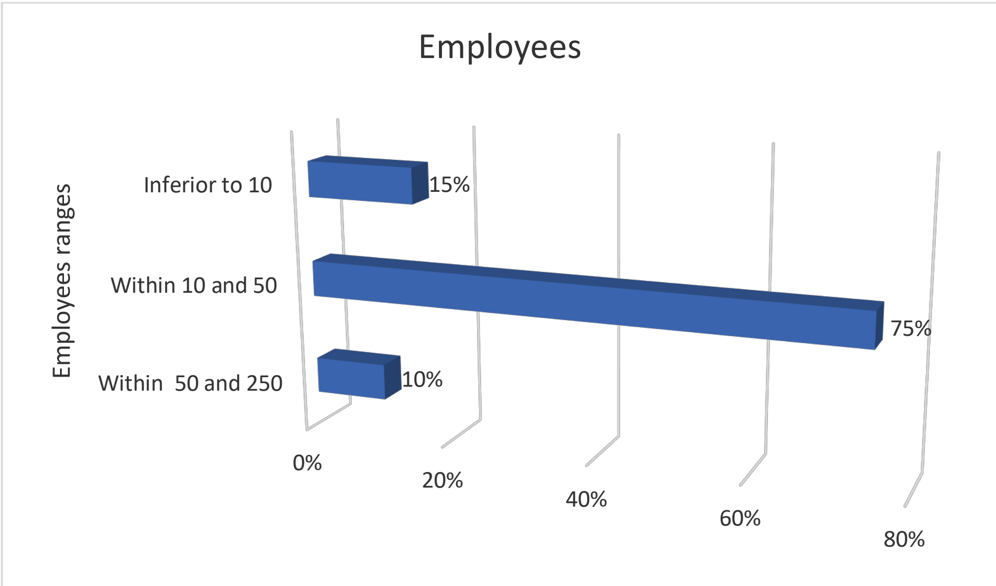


Figure 28 Enterprise's dimension expressed in employees' numbers

For aspects concerning supply chain management, 55% of the companies interviewed have one or more main suppliers that guarantee at least 30% of the MPs and / or semi-finished products. The value is not high, as in some cases it is the same customers who impose the suppliers from which to obtain supplies for specific orders. This occurs mainly in the aerospace and petrochemical sectors, where high quality standards require greater attention when selecting raw materials.

Of this 55% of companies, 46% have a number of suppliers ranging between 3 and 10. On the customer side, 80% of businesses interface with large companies, while 70% with small businesses. In addition, the percentage of turnover dependent on key customers is 75% in 45% of cases, a value that is certainly important, but which shows a decreasing trend, as over the years, companies have decided to diversify and explore new market sectors.

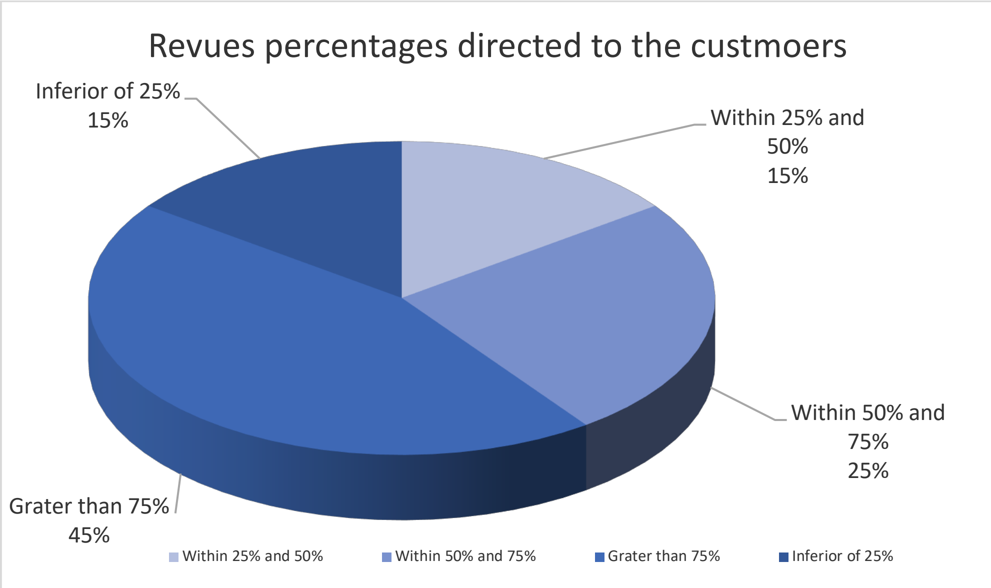


Figure 29 Revenues percentages relied on few key customers

Regarding the production aspects, we investigated the presence or absence of peaks or seasonality in orders. The result of the survey showed that in 30% of the cases there are seasonal phenomena, while in 40%, of production peaks. When this happens in most cases the internal production capacity is exploited, as it is often calibrated on the maximum bearable peak; in the remaining ones, production capacity is increased by increasing work shifts (36%) or outsourcing production to avoid losing the contract (14%).

Figure 30 Firms reaction to peaks and seasonality phenomena

An interesting result, compared to previous surveys carried out by the researchers of the ICE @ Lab, is that 100% of the sample has heard about Industry 4.0, mainly through word of mouth or seminars / conferences organized by trade associations and only marginally through the web and scientific journals.
More generally, 95% of respondents said they were aware of calls for tenders for technological development and the implementation of Industry 4.0 technologies, while only 75% said they had participated in initiatives on technological development and innovation, and finally, only 45% of the sample managed to take advantage of the hyper-depreciation and super-amortization provided for by the Calenda Plan.

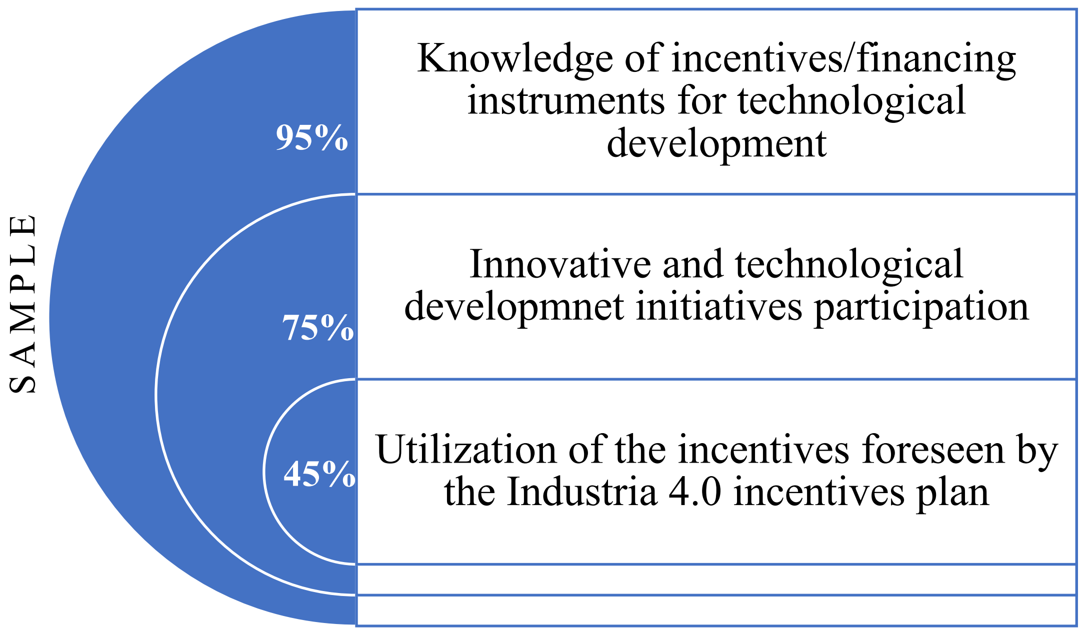


Figure 31: Results about knowledge degree of Industry 4.0 incentives

Among the various forms of incentive known to entrepreneurs, the Sabatini Law, the Tax Credit, the regional law for young entrepreneurs, the Digitalization Voucher and the aforementioned Piano Calenda are mentioned.

3.6.2 Results about Industry 4.0 knowledge

As far as the level of knowledge of the technologies related to Industry 4.0 is concerned, it is highlighted that the Cloud is the most well-known one, together with 3D printing and Smart Sensors. It follows the Internet of Things, Robotics and AI, Big Data Analysis, Virtual Reality and Cybersecurity. The Cyberphysical Systems and Wearable devices tail light.

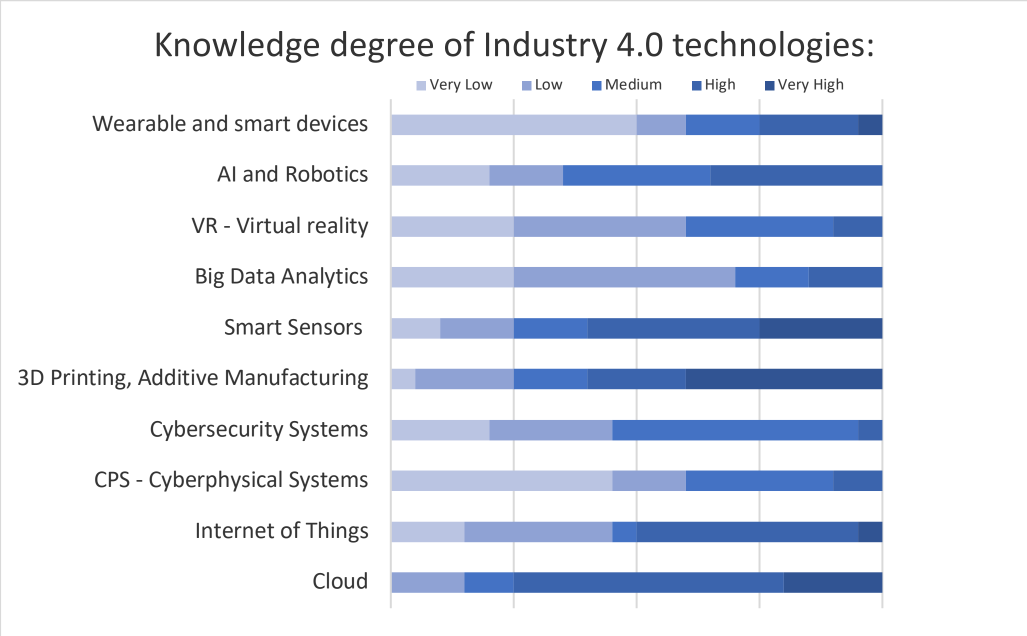


Figure 32 : Knowledge level of Industry 4.0 technologies

Given the period concurrence between the survey carried out and the deadline for the adaptation to the European data management regulations (GDPR), it was decided to ask some questions in order to assess the perception of entrepreneurs on the age-old issue of sensitive data. 90% of respondents said they knew the GDPR and had implemented at least one measure aimed at providing updated consent tools and informing the client about the purpose of the data processed. When asked whether the company would be willing to share some of its data from external services, 45% expressed negatively and only 25% positively, while 30% remained willing to make a partial selection of data.

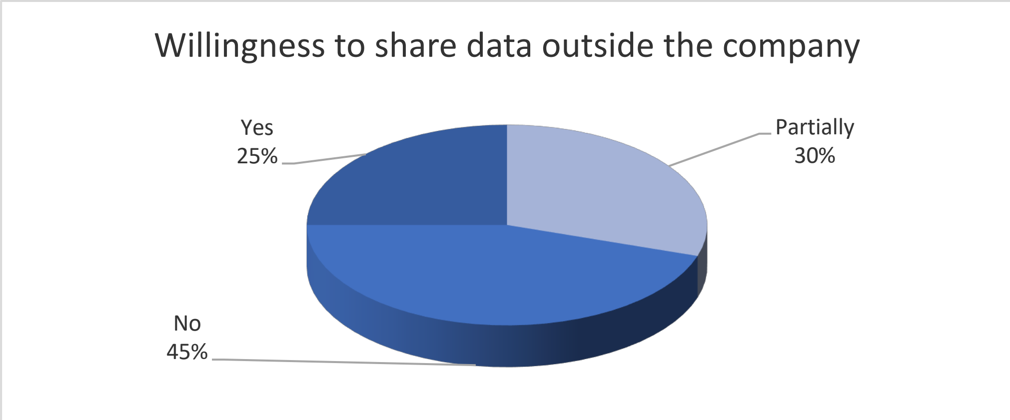


Figure 33: Company's willingness to data sharing

For those who have responded negatively, the main reason for the refusal is due to the belief that the data are personal to the company and no one else should be able to access it, while 25% are suspicious or do not see an effective economic advantage.

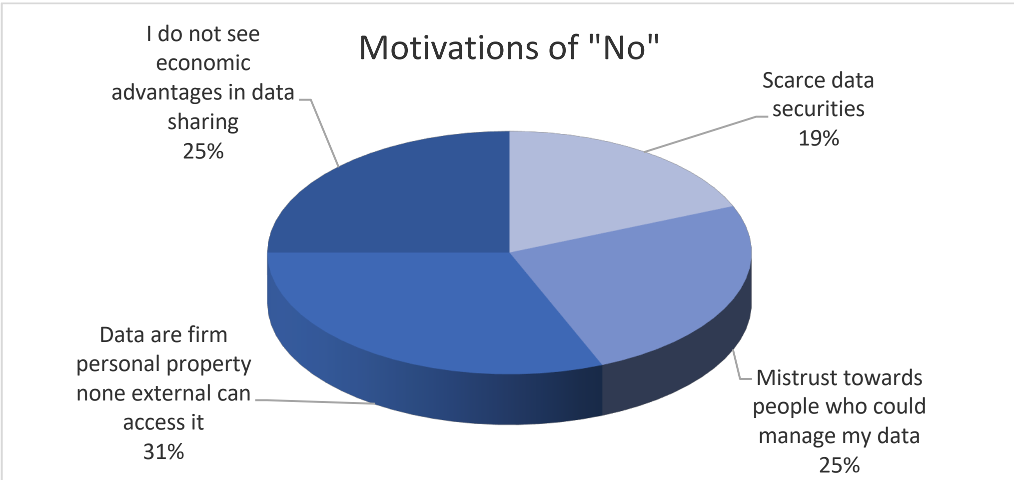


Figure 34: Firm's motivation to data sharing refuse

Entrepreneurs who responded "In part" positively evaluate the possibility of sharing information regarding logistics and production status, but negatively information on production specifications and sensitive customer data. When asked whether companies were aware of IT security criteria, the majority responded positively by explaining that the practice of double backups both internal and external is the most widespread. Of these, however, only one company has admitted that it has trained its employees regarding Cybersecurity. A very comforting figure that totals 99% is the knowledge rate of at least one Cloud solution such as Software as a Service. Of this 99%, however, only 50% adopt a solution in their own business.

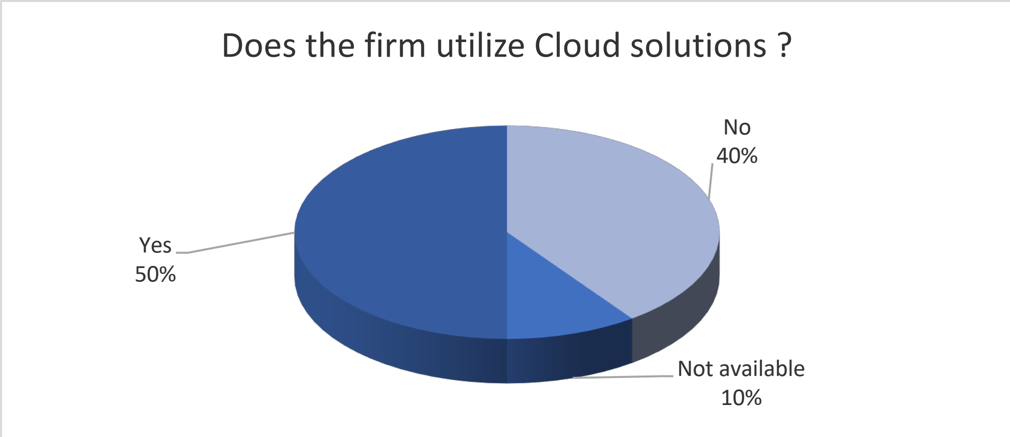


Figure 35: Firms cloud solutions adoption

The willingness of entrepreneurs to share data to create corporate cloud services is close to 65%, although 47% of the sample still considers an in-house server more secure than one in the cloud, all due to a lack of knowledge of the security offered by cloud solutions.

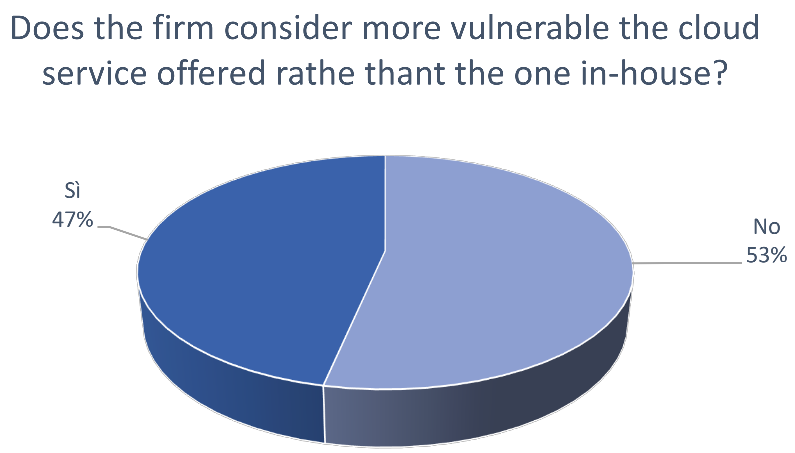


Figure 36: Firm perception of In-house data storage vs cloud solutions

The average SME entrepreneur on this specific issue was decidedly influenced by the common opinion of the public, especially regarding the recent scandals involving Facebook on data management.

3.6.3 Results: effective implementation of Industry 4.0 concepts

The evaluation of the Industry 4.0 technologies effectively implemented sees the Smart Sensors in the first place followed by Cloud and 3D Printing. The cyber security systems and cyber-physics systems rank in the middle of the ranking, a result in sharp contrast with the level of knowledge of these technologies, but in this regard, we refer to a subsequent study with focus on the engineering sector. Wearable, Virtual Reality and Big Data Analysis are the least interesting technologies for future business plans. Among the technologies of interest but not yet implemented stand Robotics and IoT. Finally, as far as corporate plans are concerned, cyber-physics systems are those that are awaiting implementation. This figure is comforting when it is precisely the union of the physical world with the computer, to be the cornerstone of the revolution of Industry 4.0. In this case the interviewed sample, although ignorant about the details of the CPS technology, seems to have grasped the possible benefits.

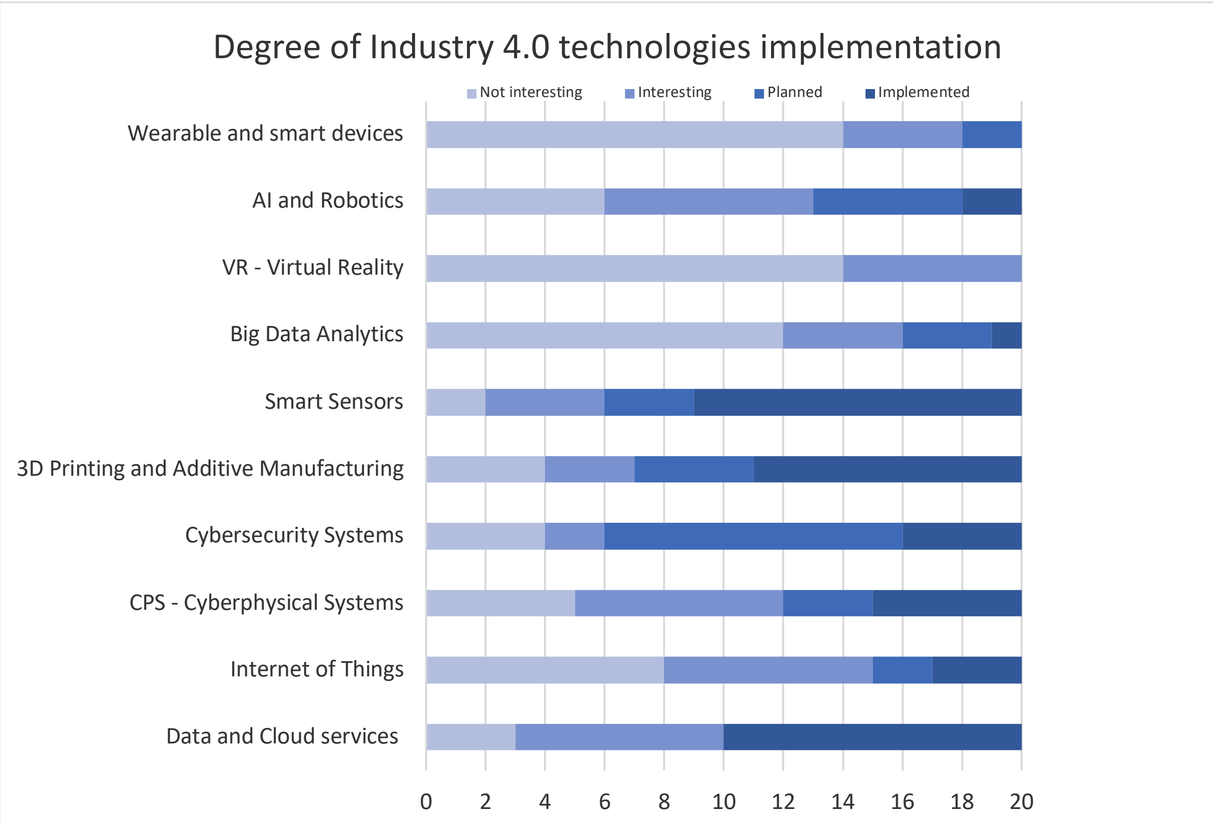


Figure 37: Firms implementation degree of Industry 4.0 technologies

The following are the activities important for the business of the companies interviewed:

Which of the following activities it is considered relevant for the firm business	*Ranking*

Small lots customization to be produced	1°
Business sustainability: with concern to environmental impacts	2°
Production process automation	3°
Firms ability to respond in occurrence of changes and organizational flexibility	4°
The use of collaborative robotics: recognized under the name of COBOT	4°
Assisted product design by the use of simulation tools and computers	5°
Planification of employee trainings about new digital tools	6°
Process analysis and monitoring through data collection	6°
Attract high specialized resources in mechatronics, electronics and computer science and automatic control	7°
R&D activities and R&D resources allocation	8°
Predisposition to offer services in addition and / or in support to physical products	9°
Definition of formal innovation plan with strategic approach	9°
Willingness to introduce innovation managers or managers dedicate to the digitalization process	10°
Vertical integration	11°
Horizontal integration	12°

Figure 38: Ranking of business important activities

In the first place, the production of small highly customized lots prevailed, a reasonable sign that organizations have caught the potential in the market for the creation of little parcels with high net revenues. It follows the automation of production processes and environmental sustainability, while at the same level preventive and predictive maintenance and organizational flexibility. Interest in master mechatronics, hardware and IT assets does not appear to be a need, just like the formalization of a strategic approach to deal with advancements. To an increasingly explicit inquiry with respect to the presence of a strategic business plan, 40% addressed that it is at present, in progress and 30% being developed.

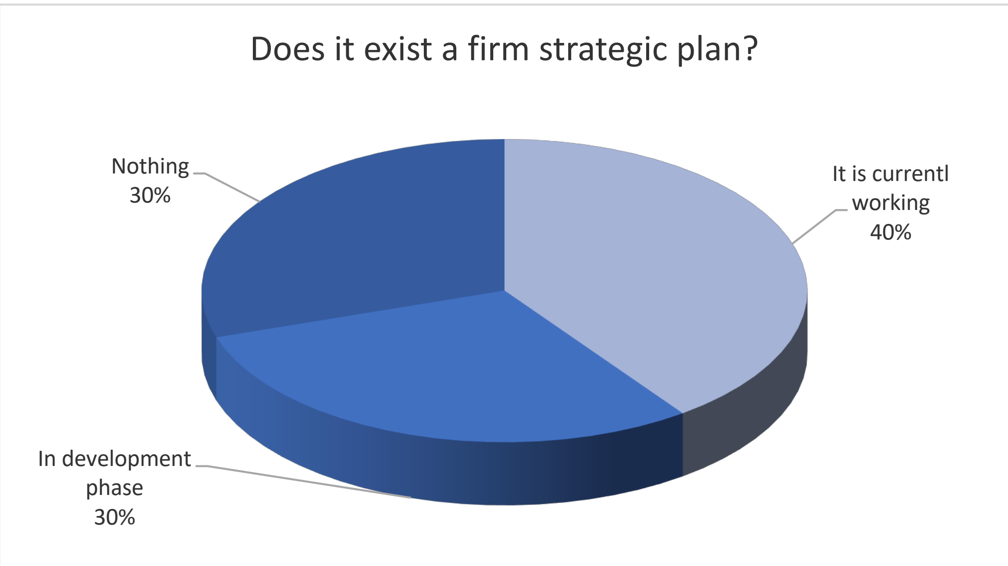


Figure 39: Existence of a firm strategic plan

During the interview this question often aroused the hilarity of the interviewees, because according to them without any plan the same companies would cease to exist in the short term. Here, however, the contradiction highlighted in Figure 38 is highlighted, as the formalization of a strategic approach occupies the last places in the ranking.

The question about the benefits expected from the implementation of the technologies in use and those that are willing to adopt, sees in the Top 3, the increase in efficiency, the increase in productivity and the increase in quality. Greater reliability and lower costs are in fourth place. It is interesting to note that the realization of customized products in small batches passes in fifth position while it was first among the important activities. The last positions in the ranking are occupied by increased transparency in the activities performed, interoperability between the various players and decision-making improvements. These three items are some of the main benefits of a Supply Chain 4.0, it is clear that entrepreneurs are not clear about the possible benefits of the industrial revolution 4.0.

Expected benefits by the as-is technologies implementation and the to-be one, with regards to Industry 4.0	Ranking
Increase of efficiency	1°
Increased productivity	2°
Increase in the quality of products / processes	3°
Cost reduction	3°
Increase in reliability of products / processes	4°
Reduction of timing (e.g. time-to-market, set-up)	4°
Increase in profits	4°
Creation of customized products in small batches	4°
Increasing worker safety	5°
Greater consumer satisfaction	5°
Improvement of the product life cycle control process	6°
Leveling of energy loads and reduction of energy use	6°
Increase transparency in their workers line activities	7°
Interoperability between the various actors, synchronization and exchange of information	8°
Improvement in decision-making	9°

Figure 40:Expected benefits by the implementation of Industry 4.0 technologies

3.6.4 Digital Twin requirements definition

After a brief technical description of the Digital Twin technology, entrepreneurs were asked whether they knew the term at least, and 55% of those answered no. Obviously this percentage was more than expected due to a widespread lack of knowledge of what a digital twin can do in the company. In fact, the next question, asking whether the possibility of real-time information on the status of the machinery having, the entire production line and the employees was useful, received 80% of affirmative answers. Thusly, 16 organizations out of 20 considered this innovation fascinating and assessed the 10 usages proposed dependent on their business exercises.

The 10 executions were the result of a careful literature survey, scanning for used ca ses and meetings of industry professionals, in particular new companies and inventi ve small and medium - sized businesses intending to bring the mechanical IoT into t he small and medium organisations.

Of the ten propositions, two emerge for genuine advancements; the first concerns the likelihood of enlisting and affirming consequently/semi-naturally all the work or exercises vital for production and perhaps furnished in the agreement. For this situation the combination of the Digital Twin with the Blockchain innovation is foreseen in order to certify the operations and operations carried out in a fast, safe and inviolable way.

The second proposal offers the possibility to receive proposals and automated indica tions concerning the compliance of the processes with the sector's ISO standards ; th e need to certify the company under a certain rule may be lost in this scenario as the digital Twin would automatically verify compliance with all specifications.

Imagine a scenario in which a customer requests to follow a new protocol, it would be enough to download the module in question, integrate it into the digital twin and automatically know if the current production is compliant and any actions to be implemented to adapt. The other 8 proposals are listed in detail in

Figure 41. the Predictive analysis aimed at signaling the future date of a machine failure raised interests of the interviewed as well as the concern to deliver a contract in time. In analogy information about the production line produced in real time and about the machinery status have been positively evaluated. The same it could be said for the storage of such data on a server. Although, the data storage represents an argued topic technology such as the Cloud produce strong doubt relates to the non-

possession of sensitive data in-house is a possible risk. Other two innovative implementations gained the third place blockchain and the IoT sensors, in this context seen as facilitator to certification procedures and the control operation. Fourth place for the controversial proposal to monitor the activity of individual employees, in this case the idea was to improve safety at work by verifying the correct use of protection devices imposed by law. Regarding the sharing of information among the actors of the supply chain, to reduce the bullwhip effect, only the sharing on the customer side was found to be interesting on average, while that on the supplier side did not, and in fact won the last place in the standings. Even the possibility of carrying out mathematical-statistical simulations has not attracted considerable interest; the proposal is in the penultimate position. In this case the motivation is mainly due to the concerns expressed by the entrepreneurs regarding the difficulty of simulating all the possible processes in a correct and reliable way.

Digital Twin Ranking	*Ranking*
Possibility to register and certify in an automatic / semi-automatic way all the processes or activities necessary for production and possibly provided for by the contract?	1°
Predictive analysis, on the collected data, aimed at signaling the impossibility of delivering a contract in time?	1°
Real-time information on the status of the machinery or the entire production line?	2°
Automatically share some of the information collected (for example, detailed production of a contract) with its customers in order to make business relationships more transparent?	2°
Real-time information on the activities carried out by employees?	3°
Predictive analysis, on the collected data, aimed at signaling the future date of machinery failure?	3°
Data collected in the cloud and accessible from any computer connected to the network and possibly from smartphones?	4°
Ability to exploit the data collected in real time to perform mathematical-statistical simulations on production processes in order to make production and resources more efficient.	4°
Share some of the information collected with its suppliers in order to better schedule their production activities?	4°
Possibility of receiving automatic suggestions and indications regarding the conformity of processes / processes with respect to ISO standards in the sector?	5°

Figure 41: Digital Twin proposed implementation ranking

The survey concludes with 4 questions aimed at understanding the propensity of companies to invest in new technologies. The first concerns the willingness to invest in the implementation of Digital Twin, the answers highlight the general interest of entrepreneurs who in most cases (40%) is conditioned to the vision of real use cases and in 30% of cases without any constraint.

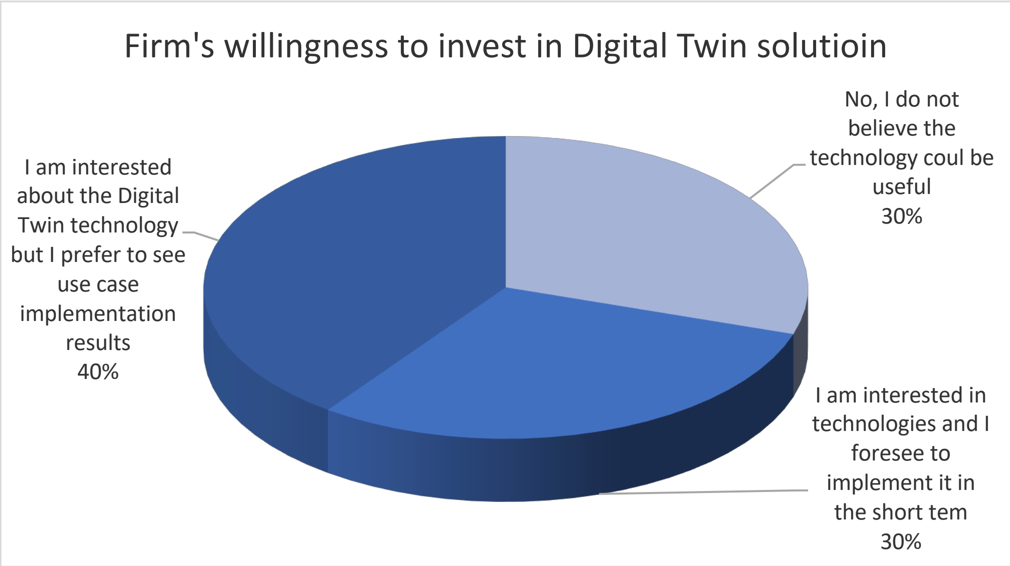


Figure 42: Firms availability to invest in Digital Twin solutions

It is therefore clear that about 5 out of 16 respondents would be willing to implement the Digital Twin immediately, thus becoming "Early Adopters" of this technology. Going into more detail, 60% of the sample said they had invested in Industry 4.0 in the last 3 years, but only 46% of them have found any real improvements.

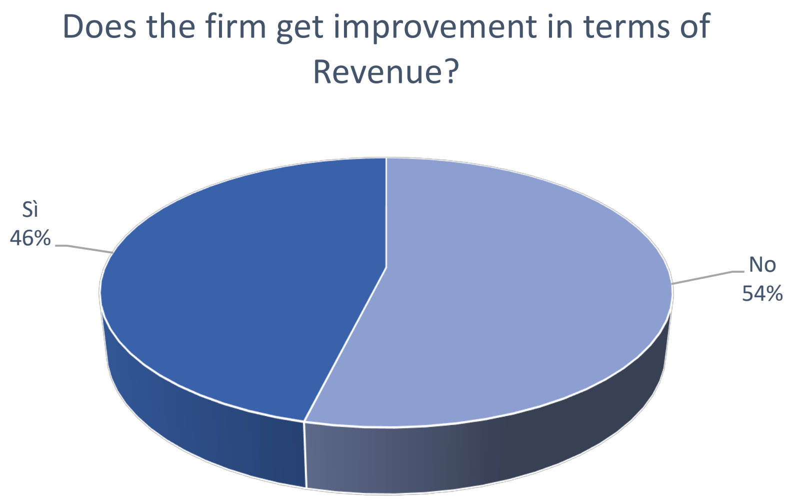


Figure 43: Significant improvement after investment in Industry 4.0

The figure is in line with expectations, as investments of this kind require a longer period of economic return, often due to the need to adapt the individual implementations to the type of production process. In general, the interviews carried out showed an improvement in production efficiency and the ability to keep the entire process under control, while only one of the respondents found an actual increase in turnover as a result of these investments. Confirming the need for a longer period of economic return, 70% of respondents believe it is necessary to wait for a medium-term period of time ranging from 3 to 5 years.

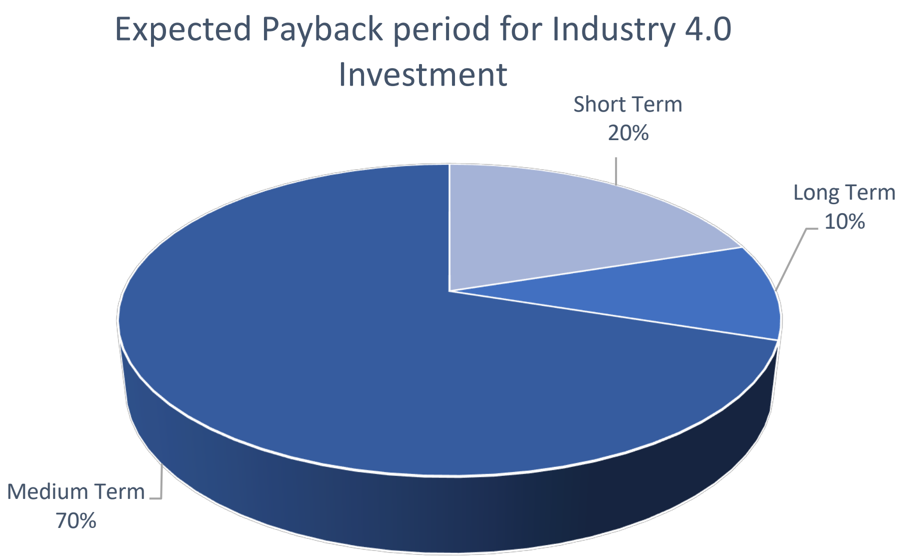


Figure 44: Expected average return on investment period for investment in Industry 4.0

3.6.5 Analysis of the automotive and metalworking segment

According to the industry investigated in the sample which in prevalence is constituted by responses deriving from the metalworking sector, and its interconnection with the automotive sector it occurs to take a sample selection decision to focus on this 2 latter sector, being the mechanical machining the real matter of interest of the interviewed companies. It follows, a series of in-depth analysis

3.6.5.1 Cross Analysis Important firm activities – Expected benefits

	INDUSTRY 4.0 EXPECTED BENEFITS	Increase efficiency	Increase the productivity	Increase the quality	Cost reduction	Increase reliability	Time contraction	Increase the profit	Small customized batches	Increase employee security	Increase customer satisfaction	Control PLC improvements	Leveling energy loads and energy consumption	Increase the transparency	Interoperability between actors, exchange of information	Improvement of decision making
Important Activities		1 °	2°	3°	3°	4°	4°	4°	4°	5°	5°	6°	6°	7°	8°	9°
Small customized batches	1°															
Preventive and predictive maintenance	2°															
Production process automation	3°															
Sustainability and energy saving	3°															
Organization flexibility and change resistance	4°															
Use of collaborative robots (COBOT)	4°															
Computer assisted design	5°															
Employees training to digital tools	6°															
Data collection and analysis	6°															
Attract STEM resources	7°															
Allocation of R&D resources	8°															
Services in support to physical products	9°															
Innovation strategic plan	9°															
Attract Innovation Manager	10°															
Vertical integration	11°															
Horizontal Integration	12°															

Figure 45: Cross Analysis Important Activities-Expected Benefits (Green = Exact Match, Yellow = Partial Match, Red = Low Match)

To get a deeper analysis over the answers gathered during the interview in the survey it is presented in a crossover analysis by crossing the results obtained by the answers of the category "Important activities for the business of the company" and "Expected benefits following the implementations of present and future technologies". From the analysis emerges that production of highly customized small lots partially matches in the two questions a, by combining a first and a fourth position respectively. It is reasonable to think that the focal point of firms is the profit and the potential marginality enriched by production customization. On the other hand, the sense of trust by the implementation of Industry 4.0 technologies resemble to be scarce. The confirmation of cross analysis positions through the 2 set of answer proposed are represented by a perfect match in order are Preventive and predictive maintenance, Processes Automation. Respectively the first one finds suitable correspondences with increase in efficiency and productivity highly relevant for the businesses the respondent. The second find in increase of efficiency and productivity a high matching level as well as and in addition with cost reduction even if it could be arguable that the first two entails the latter most of the respondents believes that is primarily important to increase efficiency and productivity rather that cut cost. Oppositely to what it could be commonly thought, environmental sustainability does not find a direct correlation with the leveling of energy loads on the benefits side, Surprisingly the theme of organizational flexibility is not reflected in the improvement in the decision-making process as matter of fact it is in the last position. Speaking about partial analogies, the position number 4 of the ranking collaborative robots correlates itself positively with increase in productivity and partially with the increase in worker safety, shown in the expected benefits table. The same conclusion and nature of relationship could be found for R & D product, the possibility to design prototype and products by the assistance of calculators and simulation tools (5th Place Important Activities) is decidedly favored by Industry 4.0, to confirm this finding is reasonable to think that the enhanced rapidity in time to market brings to a time contraction ranked as fourth in expected benefits. Going through the list, it emerges in 6th position the collection and analysis correlated with the improvement of PLC control and in part correlated to increase of transparency and interoperability among the actors. STEM resources even if not ranked in top positions represent an interesting aspect but only where directly compensated by an increase in efficiency For the rest of the items proposed in "Important activities" it has been difficult to clearly identify a direct relation to "Expected benefits" even if it interesting to underlines as the bottom part of the list is occupied by structure strategic innovation plan and managers who can ensure the results directly connected. From these latter findings it could be argued that the notions found put in evidence the backwardness of the industry regards to the transformation of the organization design in the prospect of Industry 4.0

3.6.5.2 Cross Analysis Digital Twin Ranking – Important activities

According to what defined in the previous analysis a re-elaboration of the ranking with regards to order of the Digital Twin implementation with particular attention of the metalworking sector

DIGITAL TWIN RANK RESULT	
Real time information of business line	1°
Predictive and preventive maintenance	1°
Predictive analysis for single commission	2°
Automatic ISO standard conformity	2°
Customer information sharing	3°
Blockchain over working activities	3°
Real time information about employees	4°
Data in the Cloud	4°
Mathematical-Statistical simulation	4°
Sharing information with suppliers	5°

Figure 46: Ranking of Digital Twin implementation's proposal (selected sample)

Thereafter the re-order process in Figure 46 offers a clear vision there are not particular changes compared to the one in Figure 18 over the entire sample. The noteworthy changes to be detected is the inversion by the first of the second position of the precedent list. On the other hand, by the comparison among relevant activities for the interviewed and the result of the Digital Twin ranking it is reasonable to highlight some matching. To point one with particular attention, predictive analysis for the maintenance of the machines, both its encompass a good reputation in the DT implementation and high importance in the company's business as well as the real-time information on the status of the line and the predictive analyzes on the status of the order also see a correspondence with the organizational flexibility and the change. Therefore, for the directly comparable aspects no inconsistencies emerge in the respondents' answers.

3.6.5.3 Cross Analysis Digital Twin Ranking – Expected benefits

The Digital Twin ranking comparison with that of Industry 4.0's expected benefits returns the most interesting results. With regard to the implementation of real-time information on the status of the line, there are two direct correspondences with the increase in efficiency and reliability due to Industry 4.0, whereas the improvement of the PLC control is matched for the respondents. The implementation of the automatic ISO conformity verification sees a strong correlation with the increase in productivity, and the reduction in timing, in particular those related to the quality control phase.

As far as the sharing of information with customers and suppliers is concerned, ther e is a correspondence with the increase in transparency, in this case the priority of th e interviewees is higher than the first.

The implementation of real - time employee information, use of the blockchain for processing certification and mathematical - statistical simulations, see high priority f itting with, respectively, increased worker safety, increased customer satisfaction, a nd reduced product development timing.

3.6.5.4 Cross Analysis Digital Twin Ranking (Early Adopters) – Industry 4.0 Implementation

In this section we want to identify the Early Adopters of the Digital Twin and evaluate how they are positioned with respect to the ranking of the implementations of Industry 4.0.

The graph in

Figure 47 allows you to visually identify the links present.

	INDUSTRY 4.0 IMPLEMENTATION	Internet of Things	Smart sensors	Data and software in the Cloud	Cyber-Physical Systems - CPSs	Cybersecurity Systems	3D Printing and additive manufacturing	Big Data Analytics	AI and Robotics	Virtual Reality	Wearable and smart devices
DIGITAL TWIN RANK RESULT		1°	1°	2°	2°	3°	4°	4°	5°	6°	7°
Blockchain	1°	[green]	[green]								
Predictive analysis over single commission	1°							[red]			
Business line real time info	2°			[green]							
Sharing info with clients	2°			[green]							
Employees real time information	3°	[green]	[green]		[green]						
Maintenance predictive analysis	3°							[yellow]			
Data in the Cloud	4°			[green]							
Mathematical-statistical simulation	4°							[green]			
Sharing info with suppliers	4°			[green]							
Automatic standard ISO conformity	5°	[green]	[green]	[green]	[green]						

Figure 47: Digital Twin Cross Analysis - Industry 4.0 Implementation (Selected Sample) (Green = Exact Match, Yellow = Partial Match, Red = Poor Match)

The blockchain for manufacturing activities is in 1st place and finds a perfect correspondence among the implemented technologies (IoT and Smart Sensors). The same cannot be said for the predictive analyzes for the status of the order, which should exploit the big data analysis, technology among the last places in the Industry 4.0 implementations.

The real-time information of the line, the sharing of information with customers and suppliers, the data collected in Cloud (2nd place Ranking DT) find an exact correspondence with the implementation 4.0 Data or software in Cloud.

Similarly, it happens for real-time information on the activities performed by employees and automatic ISO compliance, as can be seen directly in
Figure 47.

The only partial matching concerns the predictive analysis for machine maintenance (3rd place) that does not find an exact priority match with the Big Data Analytics implementation that instead ranks 4th.

3.6.5.5 Who decided to not invest in the Digital Twin?

DT does not raise the interest of the interviewed firm, 3 out of 5 of the respondents decided to not begin the survey phase regarding the requirements definition for the DT. For such a reason it has been matter of assessment only the degree of implementation of Industry 4.0 technologies by looking at potential correlation to this aspect.

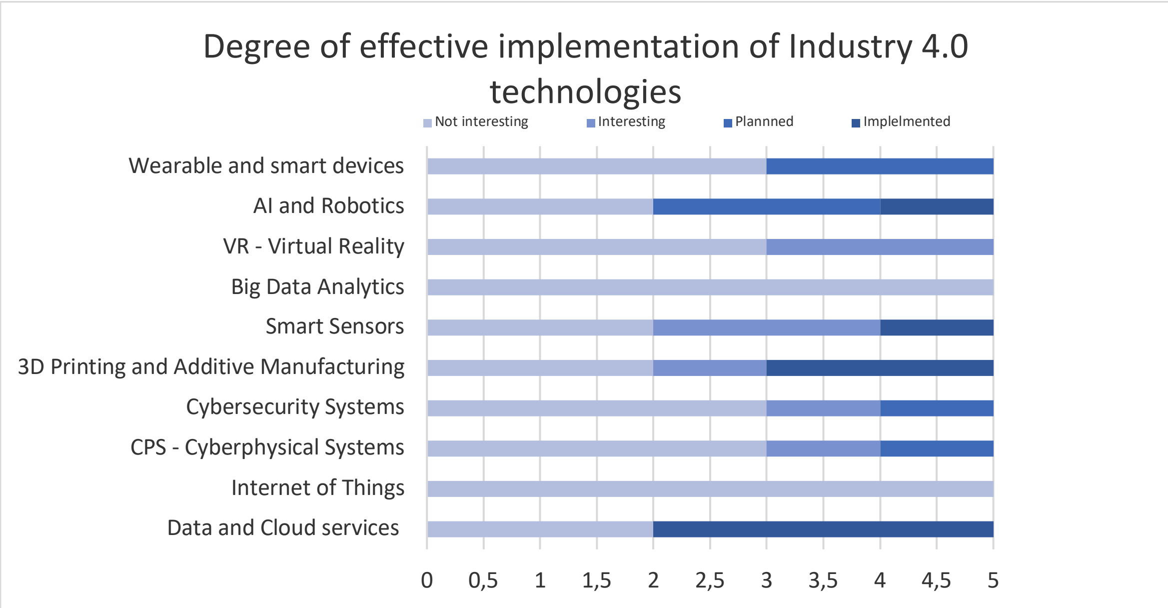


Figure 48: Degree of effective implementation of Industry 4.0 technology (sample without Digital Twin)

By analyzing the graph in Figure 48 it can be elicited, without doubts that roughly half of the respondents have not yet implemented technologies related to the Industry 4.0. The less considered and adopted are IoT and Big Data Analytics solutions. Cloud as previously as already seen in the general sample represents the technologies with the high degree of implementation. Subsequently, it follows 3D printing, smart sensors and the Robotics in contradiction to the general sample previously analyzed. It should be kept in mind that the low innovation culture of the companies analyzed here, 5 does not favor interest in technologies whose future potential is not fully understood. The examined companies are of small dimension indistinctively in employees' numbers and turnover for such a reason a high capital-intensive investment in new technologies would requires years to be absorbed.

4 A particular case in the survey: Business Network

4.1 What is Business Network?

In academic literature, especially with reference to the marketing and market positioning strategy theory, a curious aspect is raised by the concept of Network of Business or even defined According to (James C. Anderson, 1994) as “A business network can be defined as a set of two or more connected business relationships, in which each exchange relation is between business firms that are conceptualized as collective actors. Connected means the extent to which "exchange in one relation is contingent upon exchange (or non-exchange) in the other relation". The nature of the relationships can be both direct and indirect enabling the perspective of an even larger networks.

4.2 Industry 4.0 Business Network: Real use case

During the survey about the Piedmont SME conducted, as presented in section 3 , a real use case of Network business was present among the interviewed firms. The peculiarity of this real use case is the Network of Business in the Industry 4.0 context. As matter of fact thanks to the new dimension of smart factory, the possibility to constitutes heterogenous business able to match demand with products and services which are not the core of their business becomes a concrete opportunity. The developments of network business based on complementary services and products is facilitated by the digital attributes of each single firm. It could be noticed that the digital attitude of an enterprise reinforces its possibility to develop rapidly.
Industry 4.0 technologies open to new network business scenarios.

1. The production line enabled by the Digital Twin could be shared in the network to be accessed by all the member of the network. Contemporary M2M and IoT marketplace can give born to regulated marketplace where economics agreement between partners of the business network enable to trust each other,

by the self-regulated exchange of information between production machine, even remotely.

2. All the information exchanged, and data asset of each firm are tracked and monitored by digital solutions. In such a way the control over the network is assured by the network itself rather than on the trust among companies, that in traditional business network ends to be in control by the largest firm.

The advantage for SME that intends to be part of the business networks are numerous and noteworthy:

- Enhanced visibility on the market
- Possibility to face markets that otherwise could present entry barriers not sustainable for small dimension enterprises
- Possibility to saturate the production capacity by avoiding waste and enjoying greater return
- To develop alternative products for multiple markets
- To participates in long term strategic plan and economic incentives otherwise not accessible
- To compete with superior dimension enterprises
- Acquires new capability and complementary know-how otherwise roughly inaccessible

4.2.1 Business Network case from the Survey:

For simplicity the identifier of the Business Network case from the survey in this thesis will be Net01.

Founded in 2018 the Net01 as mentioned on its website (Hub 22 Network, 2019) is "a container of shared ideas among synergic companies which develop hi-tech products and services ". Net01 born in Ivrea by the union of 4 companies each with different but complementary know how in the field of mechatronics:

- Firm1: mechatronics specialized manufacturing firm
- Firm2: innovative IoT solution firm

- Firm3 : engineering solution provider
- Firm4 : metallurgic specialized manufacturing firm

In Figure 49 an overview of the Industry 4.0 based model offered by Net01

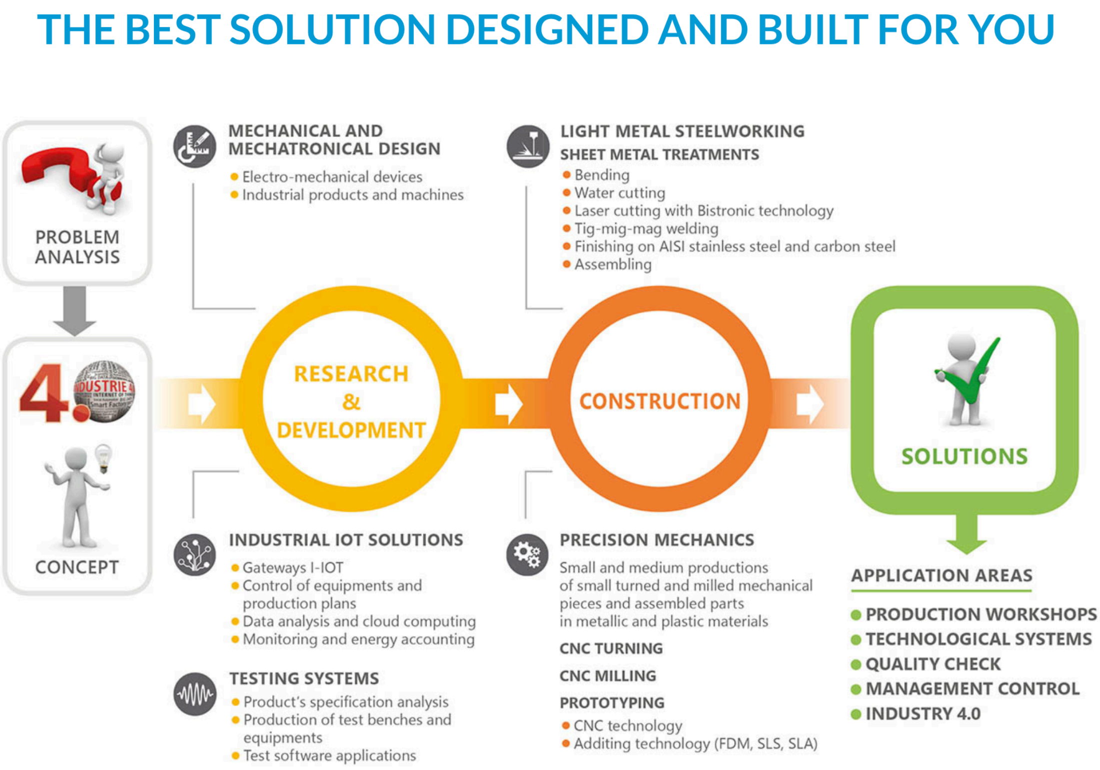


Figure 49: Hub 22 network of business scheme, source (Hub 22 Network, 2019)

The founder of the network is the same person who found Firm1 and that participates to the survey described in chapter 2. The participation to the survey will justify the focus on the description of the industry 4.0 model of the SME Firm1 which it is mentioned in this thesis as a virtuous case of Industry 4.0 concept application. It follows a list of technologies already implemented according to the answers given during the survey

Technologies	Degree of implementation
Data and Cloud services	Implemented
Internet of Things	Implemented
CPS - Cyberphysical Systems	Implemented
Cybersecurity Systems	Implemented
3D Printing and Additive Manufacturing	Implemented

Smart Sensors	Implemented
Big Data Analytics	Planned
VR - Virtual Reality	Interesting
AI and Robotics	Interesting
Wearable and smart devices	Interesting

Differently from other interviewed company even the approach of the firm's entrepreneurs have been curious towards the adoption of new enabling technologies rather than showing the usual skepticism perceived by the majority of the sample as it can be elicited in Figure 48. The open cultural mindset felt during the interview confers to the interviewed firm a confirmation of what sustained by data.

4.2.2 Firm1: history and markets

Firm1, founded in 2007, is a company that produces small metal goods and precision components for direct customers at international level. The industrial sectors which is used to serves are:

- Photography: manufacture mechanical parts of photographic products such as photographic sliders for shooting, which we also re-engineered.
- Industrial vehicle: by the production of mechanical components for industrial vehicles of the earthmoving sector for one of the most important company of the world.
- Medical industry: components for replacements, screws to treat bone fractures and even in dental components supply such as for titanium implants
- Banking automation: last but not least the core business, manufacturing of mechanical parts of machinery for the banking automation industry, the main customers operates in this industry serving clients all over the world
- Mechatronics: mechanical components for machinery and testing equipment.
- Motorcycling: racing components for motorbikes (e.g. pedals, clutch levers, counterweights, bars, spacers, bleed valves, dumb terminals, brake groups, etc.).
- Sport equipment: parts for outdoor sports and underwater fishing equipment.

4.2.2.1 Ongoing Projects in Industry 4.0 context

- Firm1 has start a pilot project of the MES (which links machinery and processes) according to the principles of Industry 4.0, Figure 50.

Figure 50: MES scheme, source

To enable the MES project the collaboration with the Firm2 company, partner of the Net01 network business, has brought to the born of the product that facilitates the digitalization of the company. The Grimmy, an IoT hardware solution proposed by Firm2, becomes a key component of the digital transformation of the company in a Smart factoy, Figure 51.

Figure 51: Grimmy IoT solutions integration, source (Robson Srl, 2019)

The offered solutions mainly concern in the hardware gateway that permit to digitalized old machineries and interconnect them and interfaces in the exchange information protocol to become available data in databases, in this solution Oracle one. The data at disposal over databases can be offered to high level management software, such as the MES, A particular case in the survey: Business Network

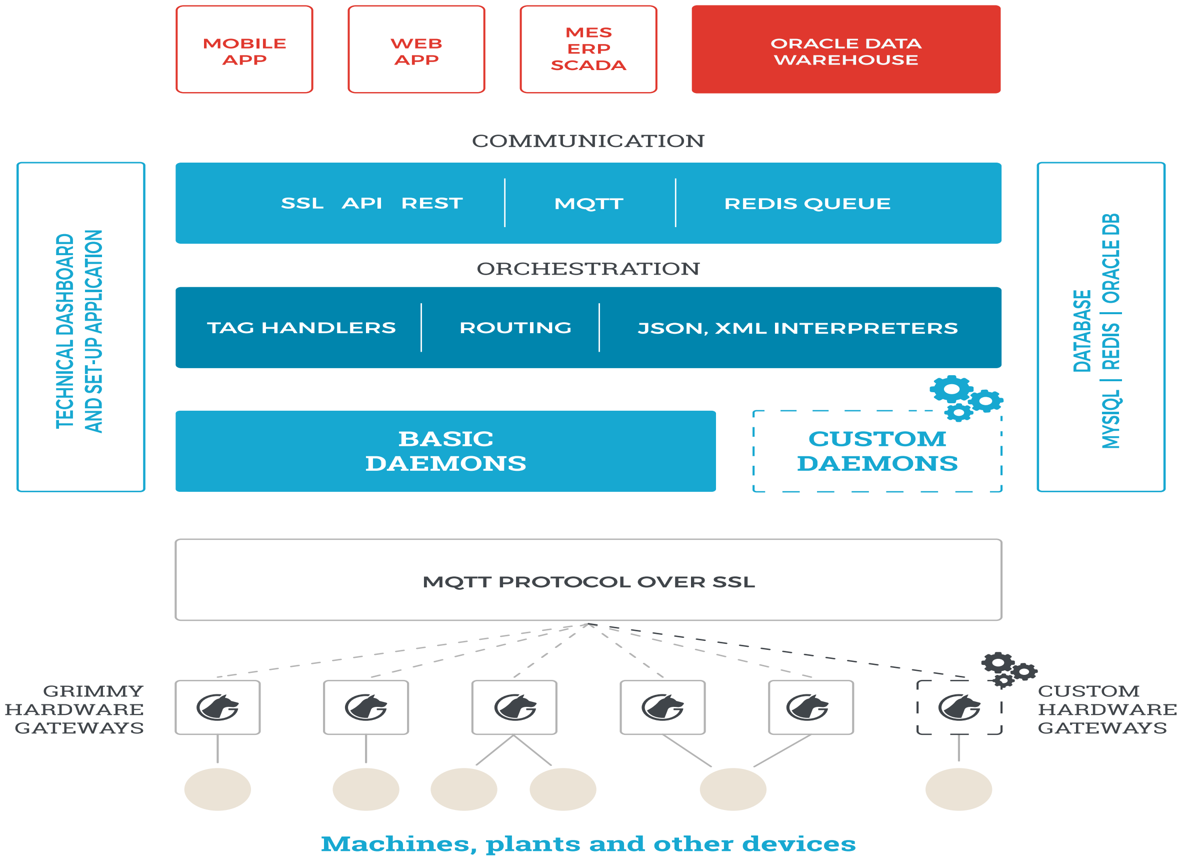


Figure 52: Grimmy technical solution overview, source (Robson Srl, 2019)

- Electronic Tool Magazine: automated system ensures the management, control and delivery of mechanical tools through an automatic counting system which considers the tools collected reducing time wasting and mistakes.

4.2.2.2 Competence creation and Awareness of Industry 4.0:

- The founder is teaching in a post-secondary school IFTS mechanics course; he collaborates with technical and professional schools and supports dual training system learning and working projects
- The founder's wife is coordinating a project aiming at developing new career guidance initiatives and the relationship between school and companies which has been promoted by the "Developing Plan for Canavese"

4.2.3 Business Network and M2M economy

As will be discussed in details in Chapter 4 , M2M economy fits with industry which involves highly intensive machine's use and where massive amounts of data can be produced. According to what described in this chapter, network of business especially in the manufacturing industry, can exploit all the advantages brought by sharing economies enabled by Industry 4.0 technologies and IoT in which the “Things” become sharable asset within the network. Machine economy could enable agreement among companies of the network to better supply external customers, or even regulates “Smart contract”, enabled by blockchain technology, between the members of the network itself. The shift of trust towards a shared platform, such as the one proposed by the Digital Twin, could enable a new frontier in the network of business constitution. As matter of fact, one of the criticalities showed by the network of business scheme, regards the trust among firms involved as well as the leading decisional role that usually it is assigned to the valuable firm within the network. For such a reason, transparency assured by machines data, associated to autonomous entity on the network, becomes a precious aspect over which to build new trustworthy relationships.

The machine economy applied to business network could enable advantageous scheme for SME:

- Machines autonomously could enable real time transaction, in occurrence of expected results, based on prior settled agreements among the network business members.
- The possibility of the network to be perceived by external customer confers a unique advantage for SME to be opened to vast market that otherwise would have been inaccessible.

5 Machine to machine Economy M2M

5.1 What is M2M?

Recently in the technological innovation environment it has been matter of concern the concept of M2M machine-to-machine communications. Although some consider it, has the next revolution after the Internet and computers, some other show skepticism with regards to high tech bubble which grows in the hype phase (Marco Cantamessa, 2016)

of the introduction of a new innovation. In support to the argues emerged in recent times, it could be noticed that is a decade that people involved in embedded system projecting are used to deal with communications among components, devices and systems. For such a reason the M2M topic could looks like to them as a renaming process of an already existent communications protocol. Despite of all, this last assumption it is put under discussion, according to (Swan, 2018, February) Cisco estimates that communication exchange made by M2M is grown by 84%, faster than any other communication protocol category. It is importance to notice within this context that even though M2M tripled in the IP traffic forecast from 2012 to 2018 the composition is shifting in favor of mobile connections. As matter of fact, M2M intends to address the management on an increased complexity which marks a profound difference from the traditional protocol used until today. In particular, M2M intends to utilize an entire ecosystem of interconnected devices, proposing different architecture solution compared to the one recommended in embedded system design. Gartner foresees that just the interconnected devices for the IoT market will be 26 billion by 2020. This last evidence profound the feeling about the increased information exchange complexity that these technologies will have to face.

To address the increased level of massive amount of data M2M will serve itself of new enabling technologies, further discussed below, and modern mobile telecommunications infrastructures, especially with the introduction of the 5G and 4G which facilitates the creation of new services and products.

The Figure 53 below offers an overview of the process scheme which M2M could create at a very high level.

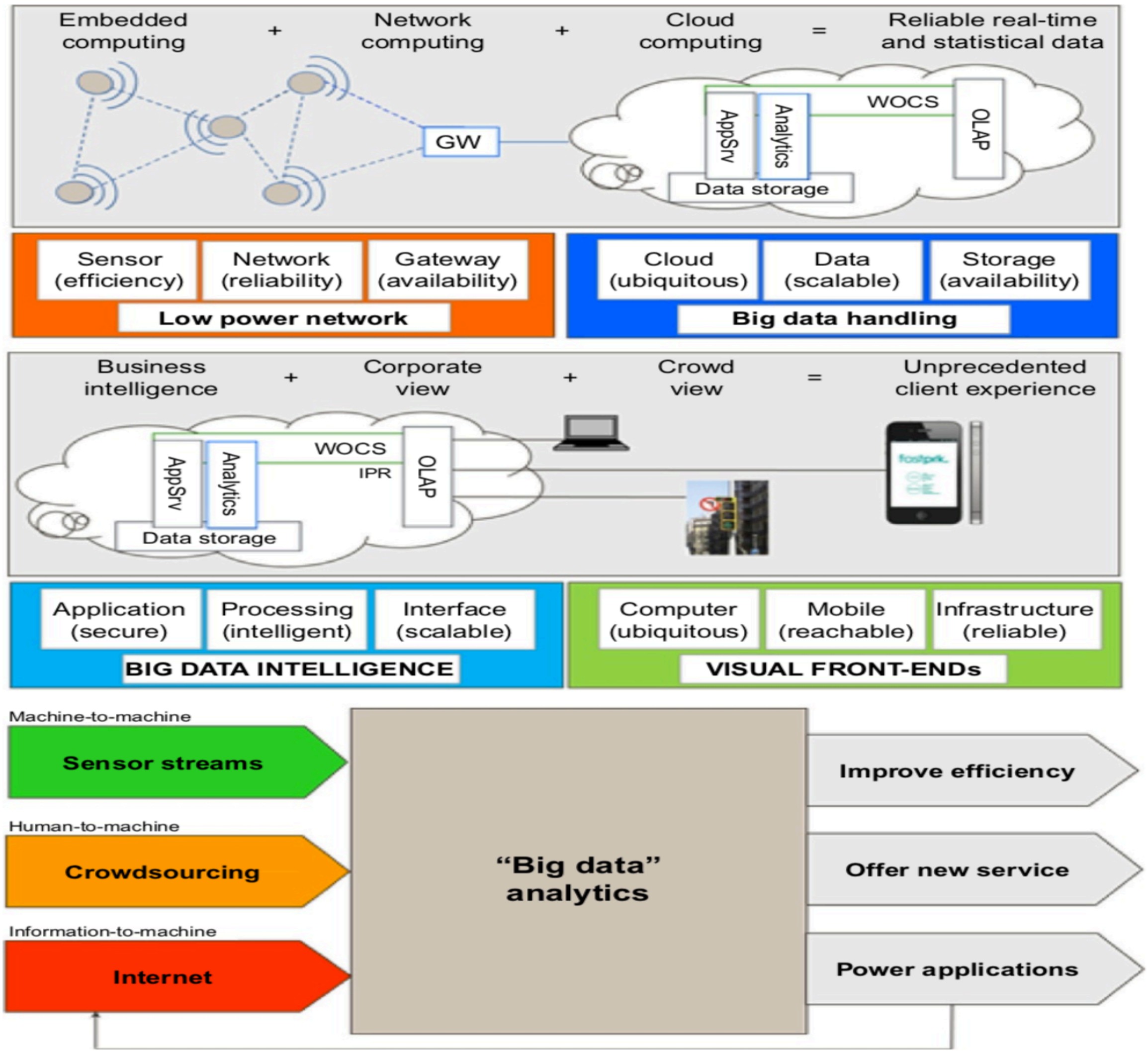


Figure 53: M2M overview of turn-key solution, source (Carles Anton-Haro, 2014)

Mainly, the new M2M paradigm is empowered by the implementation of:

- new techniques of distributed computing
- information aggregation resulting by the usage of the Cloud

Although, new technical innovations help the development phase of the M2M the main effort is concentrated on the introduction of a shared communication protocols due to the diversity of the actors involved in the process. Achieving standardization in messages transmissions among machines would introduce great advantages (Carles Anton-Haro, 2014):

- Reduce latency in information exchanges
- Empower effectiveness in the provision of the services

- Provide real time information: the interconnected devices in real time could transmit information supporting decision-making based on deeper analysis through prior collected historical data
- Introduce the management of heterogeneous data: unprecedented insights in terms of data heterogeneity, resulting by the integration of multiple sources allows a broad perspective about behaviors and trends.

Furthermore, the M2M architectures address some traditional issue within the context of systems management, bringing remarkable benefits over:

- *Enhanced reliability:* users can rely on systems tested, calibrated and certified. Through monitoring of similar nodes, it becomes easy to recognize issues and to take corrective actions on it. To rely on nodes conglomerate introduces resilience in the overall system:

    - Prevention from unforeseen shutdown
    - Isolation of technical single nods issues
    - Enrichment of disaster recovery strategy

- *Advanced Cybersecurity:* each node it has to be considered as an isolated entity which enables the exchange of information with the others constituting a unique and independent by the others. This offer greater level of security avoiding entire system sufferings.

5.2 Enabling technologies:

According to the description proposed in the previous section M2M is in continuous evolution. Because of its high novelty content, the M2M still has to definitely find the fit-for-purpose technology in support. On the other hand, it seems in the recent years that some emerging technologies are matching the M2M requirements and unprecedently pushing the M2M concept towards feasible realization. Some of the proposed technologies have been already described in chapter 1, some others will be offered in this section.

1. IoT: The physical nodes composing IoT will be the principal actors that will enable the information exchange made by M2M protocol
2. Blockchain:

   The blockchain origin derives from the invention of the cryptocurrency (virtual currency) Bitcoin. Blockchain it is a particular form of IT architecture that allows the creation of a decentralized information system information storage. According to (Swan, 2018, February) the blockchain is a public ledger which stores all the transactions recorded by Bitcoin exchange. The blockchain is in continuous evolution. As matter of fact, as long as a new Bitcoin is created (in jargon “mined”) a single block increases its volume by adding the new bitcoin created. The bitcoin and the block creation are the key innovative components of the blockchain. To “mine” a bitcoin and to add it in a block the “miners” have to solve a computational problem which is estimated to be solved in a defined period of time, roughly ten minutes (in the Bitcoin application). In exchange to their computational contribution “Miners” are rewarded by a unit of currency. The computational power deployed to solve the computational problem ensure the network about the intention of miners which basically, have the task to validate each block.

   The reason why they are called to validate the block and each transaction included in it, underline the innovation introduced by blockchain. As matter of fact each transaction and block are shared over each node composing the network, hence the name of “Distributed Ledger”, Figure 54, of the blockchain ensuring transaction transparency and security.

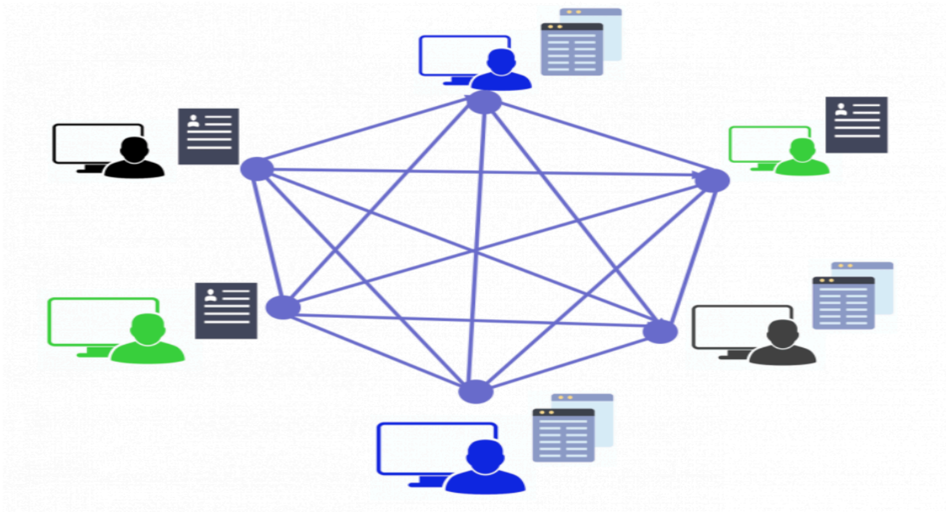


Figure 54: Distributed Ledger structure, source (Bellini, 2019)

To validate the block and transactions at least half of the node participating the network should agree and validate the composition of the transaction, made by:

- ID of sender: digital signature and sender's public key dos
- Information of the transaction
- ID of receiver: receiver's public key

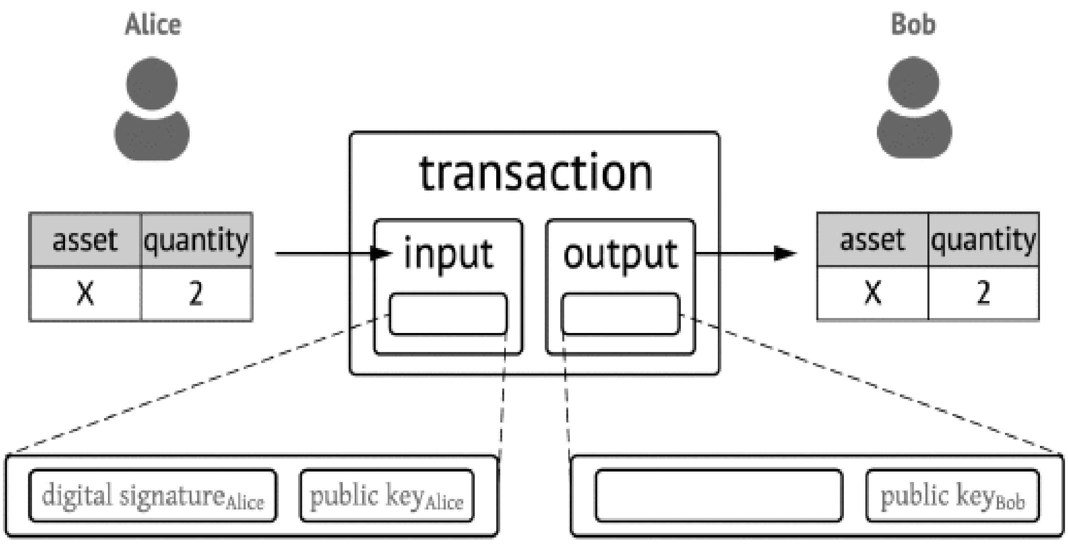


Figure 55: A transaction that transfers a tokenized asset (X) from Alice to Bob. Alice signed her input, and created an output locked against Bob's public key, so that only Bob can spend it, source (Devetsikiotis, 2016)

The shared validation process of each transaction and block constitutes a new transaction's scheme based on consensus of participants rather than on a central authority governing and controlling each transaction. The trust in the transaction shifts from a central authority to a distribute one governed by democratic consensus of each node over the network.

Each node gives a digital consensus implemented by an algorithm in charge to confirm the IDs of sender and receiver as well as the information include in the transaction are unique and not replicated.

To sum up, the main advantages of the blockchain regard:

a. *Decentralization*: information and transactions are decentralized and owned by each node composing the network
b. *Transparency*: information and transactions are recorded in such a way, by the use of timestamp and public sharing, that each node of the network can investigate trough the “Ledger” about transactions
c. *Security and Immutability*: the distribute ledger guarantees resilience for lack of information by some nodes, the rest of the network store the same updated information, or eventual cyber-attacks. Furthermore, each transaction deploys high level of cryptography and the structure of the blockchain network intends to implement a zero-vulnerability system. As matter of fact as shown in Figure 56, each block of transaction in concatenated to the previous one in linearly and cronologically, when the last block is created and validate it is added at the end o the chain.

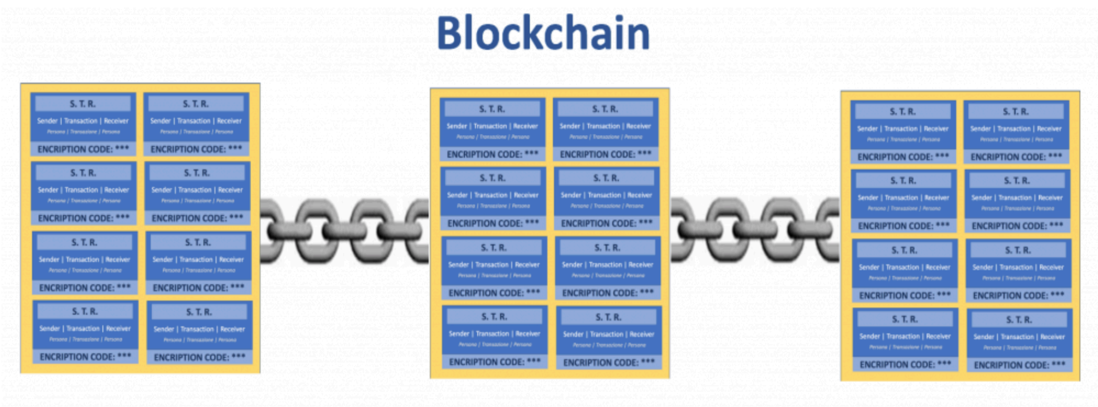


Figure 56: Blockchain structure, source (Bellini, 2019)

To modify or explore the information content of a transaction contained in an initial block, it should be solved, by using a massive computational power, the algorithm of each block and each previous transaction of the desired one

a. *Consensus*: the consensus mechanism activated by the block and transactions approval is in fact the innovative concept that shift the trust over the network participants instead of a central authority. This topic impacts remarkably costs. Intermediary-fee transaction are not any more contemplated with this scheme being avoided the value added by the entity in charge to profound trust "service".
b. *Digitalization:* blockchain technology becomes a new key enabling technologies towards digitalization of information. Although, it finds its first application in the virtual currency the prospects of blockchain applicability move towards each industry where transactions of information are involved. Any currency, financial contract, or hard or soft asset may be transacted with a system like a blockchain. In particular it could have positive impact on bureaucracy facilitation and Smart contracts, contracts that execute automatically contractual condition autonomously (Devetsikiotis, 2016) , to cite some of the possible applications.

c. Digital Twin: As extensively presented in chapter 2, Digital Twin constitutes a key enabler for the M2M solutions. Thanks to its essence of simulation environment and optimization process it could support the development and the design of M2M communications among the twins of components. The Digital Twin platform could begin to assume a crucial role for M2M, becoming the platform over which to implement the M2M communication protocol.

5.3 M2M economy: business model

The M2M solution represent a challenging technology in the actual markets, opening to the consideration of innovative business model opportunities. As matter of fact, the high scalability level introduced by the massive amount and variety of devices allows possibility to leverage and shaping business applications and rapidly scales up to others. The flexibility introduced by M2M not only enlighten company about business development but enable the perception in the customer that well-adopted products or services can designed according to him/her exigencies. For such a reason, customization becomes a new reliable trend over which to build business model even unprecedently unexplored (Carles Anton-Haro, 2014). According to the literature (Carles Anton-Haro, 2014) , at least four business model logics can be identified to classify the permissible and applicable business model to M2M:

- *M2M solutions purchased by an end user as a fundamental part of a product or service*
- *M2M capabilities funded by an end user as an optional add-on to a product and or service:* the possibility to have real time information and large amount of data to analyze enable firm to customize services according to each specific on demand requests by differentiating and setting automatically different service's modules on the same product. A common use case that enable to grasp the concept of this business model regards washing machine. Due to the vast market segmentation, washing machine producers and engineers have to design complex product and take decisions and face tradeoff to serve all the possible target customer by the provision of a unique product, (e.g. standards washing machines programs). To address this category of business model issues M2M can provide alternative product customization solution by selling a standard platform to be enriched by add-on service modules and products.
- *M2M solution funded by a content provider or other suppliers:* the cost in this business model become covered by the suppliers that use the product as a distribution channel, such as in the case of book providers on the kindle which basically cover the costs of the Kindle maintenance system.
- *M2M solution funded through increased efficiencies*: with regards to this last aspect, M2M acquires a new perspective. According to the literature (Carles Anton-Haro, 2014), the most interesting form of business model entails the increased efficiencies deployed by M2M. The possibility to monitor the asset and enhance its productivity by allocating the provision of services only in occurrence of demand opens the new cost saving scenario and improved performance. Insurance industry in this context can be identified as one of the principal beneficiaries. The concept of UBI (Usage based insurance) with M2M

becomes a practical implementation of innovative business model where both automotive insurance company and customers could benefit from. On one hand the company could control the driving practices by savings costs and being more precise. On the other hand, the application of more accurate pricing system can allow the company to monetize and increase its margin.

The possibility to create cost savings and new source of revenues enable the company to differentiate themselves in the market. As differentiator the company could potentially enhances its competitivity, and in an industrial world where technology is considered a differentiator's driver, the adoption of such a technology, which even affect business model, could lower the firm's risk of being outcompeted.
In conclusion, it is meaningful to underline that the business model cited are not mutually exclusive. The composition of more than one of the aforementioned business models could lead to innovative mix with even higher potential.

5.4 Sharing economies for M2M

Nowadays, the sharing economy's model is growing as innovative business model enabled by the digital community created over the Internet, to cite the most famous one Airbnb and Uber. Thanks to web platform people can offer and share physical asset by matching the demand for a physical asset with the service provision of personal owned asset. The crucial benefit brought by this scheme entails the creation of a win-win situation both on demand side and supply side. As matter of fact, the demand could rely on a pay-for-service approach for a specific asset that otherwise would have an initial cost difficultly sustainable. On the other hand, the supplier could enjoy profit for a purchased asset that can reduce progressively its depreciation cost.

Although, sharing economies are impacting different industries and are producing unprecedent source of revenues for such users that are not used to run businesses or whose intention is to integrate and deploy the use of platform as a new distribution channel, it can be said that sharing economies are still subject to errors and misunderstandings leading to inefficiencies. The main source of wastefulness of the

internet and consequently the web platforms running on it, according to Kevin Ashton the person who coined the term IoT, is human contribution to data entry and decisions over business choices, as assumed in (Ashton, 2009).
The key aspect introduced by this last topic underlines how sensors are more efficient in observing, identifying and understanding the worlds input rather than human that have firstly to insert data manually and after to check and validate data and their analysis.
The introduction of sharing economies based on machines actions could lead to great improvements, for specific industry that base their business on easily measurable performance.

To better grasp in what sharing economies can be intended disruptive, it is possible to identify by the analysis of value perception how it varies from in industrial economy to information economy. According to Figure 57, the components of value shifts from the value perceived as exchange value in traditional Industrial economy to use value of information economy. Namely, economy based on information keep the value in its use rather in its exchange, being information roughly costless and easy to be replicated. To keep record of value the traditional double-entry bookkeeping system is substituted by new enabling technologies, in (Alex Pazaitisa, 2017) through the use of blockchain, to keep trace of all the information and avoiding its replication by preserving its uniqueness and property.
A radical change in the definition of economic value is offered within this context by the introduction of the CBPP, Common-based peer production, coined by Yochai Benckler (Benckler, 2016)

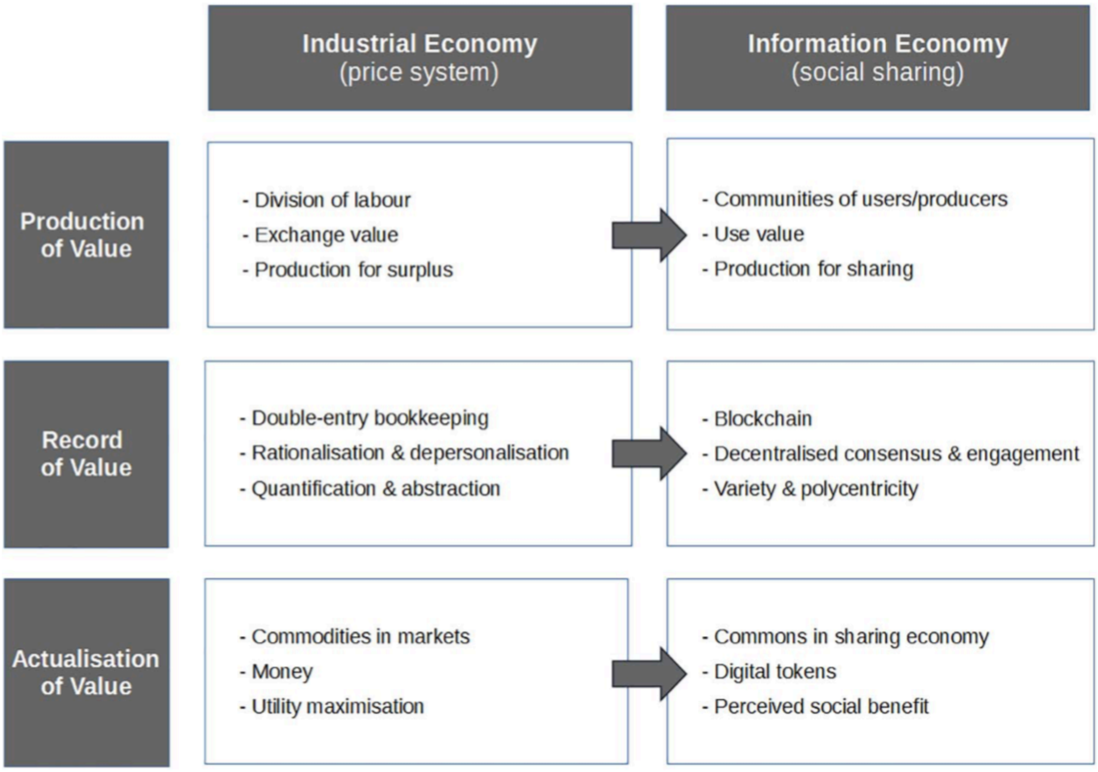


Figure 57: Comparison in value shifts from industrial to information economy, source (Alex Pazaitisa, 2017)

According to (Adam Arvidsson, 2016) : " Benkler created the term CBPP to describe forms of production in which, with the aid of the Internet, the creative energy of a large number of people is coordinated into large, meaningful projects without relying on traditional hierarchical organizations or monetary exchanges and rewards".

To the shift in value perception corresponds innovative actualization value that practically translate an alternative to money into a token, the virtual object of the transaction by the most intended, in a restrictive consideration, a digital currency. A digital token, convert the sense of value not only in what is perceived by the use of a product or a service at stake but a further benefit, gained by each user, to have access and be part of the ecosystem.

5.5 Real Use case application:

A real use case application of the M2M economy it is presented in this thesis according to what found in literature. In particular, it will be described a proof of concept based on the enabling technologies previously described in this chapter namely the Blockchain and IoT.

The project proposed regards a charging, billing and auditing system for EV (Electric Vehicles) which nowadays represents a spread argument discussed in the automotive sector. According to (Dragos Strugar, 2018) the actual charging, billing and auditing manual system for EV is inefficient for the next generation of EAV (Electric Autonomous Vehicle). For such a reason the academic literature has begun to show interest in the creation of a framework for EAV requiring the creation of secure, efficient, automatic and scalable billing and auditing system (Dragos Strugar, 2018).
Assuming that the modern EVs and EAVs will constitute a fully-equipped technological system made of high-tech network of sensors, it is plausible to conceptualize cars as IoT ecosystem. To exploit the great potential brought by these enabling technologies DLT (Distributed Ledger Technology) such as the blockchain represents a valid infrastructure over which constitute micro-payments services for M2M economies that can be applied to the automotive industry.
In the framework presented by (Dragos Strugar, 2018), it has been used the DLT technologies IOTA, a particular DLT that alternatively to other blockchain solutions pose its objective in the creation of agile and flexible infrastructure for micro-transaction, the tangle (Popov, 2018). The IOTA platform born with the aim to become the platform and standards protocol over which build the machine economy for IoT transactions (Foundation, 2019) and therefore it presents all the target characteristics needed:

a. Zero fee transaction: transactions fees are roughly inexistent compared to the value of information they vehicle
b. Low energy resource requirements: in order to satisfy the applications to devices and sensors which detains low level of energy
c. High scalability: as long as the network activity grows the transaction settlement times becomes inferior
d. Offline transactions: even in absence of continuous devices connectivity IOTA is able to be self-sustainable and updates the network data with smart algorithms
e. Secure data transfer and quantum computing resistant: according to (Popov, 2018) the tangle structure it’s able to ensure data protection resistant to the quantum computing power of the next computing generation.

To realize the Proof of Concept of EAV charging and billing architecture, 3 different layers have been developed, Figure 58:

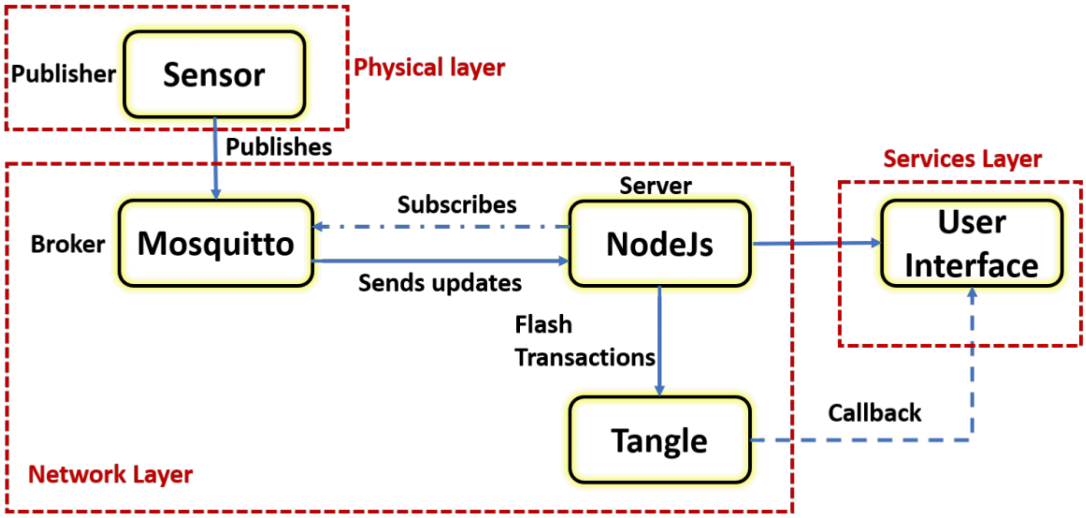


Figure 58: Communications architecture of POC experiments, source (Dragos Strugar, 2018)

1. *Physical layer:* it mainly deploys the use of sensors both on the EAV and on the CS (Charging Station/Service). The physical layer of CS encapsulates the embedded hardware components controlled by the key enabler the MC (main controller). At this stage the EAV gests energy needed at a right price depending on real time fluctuations thanks to. At the end of the energy transfer is the data accumulated during the energy transfer communicates the right total price to be paid. The MC at the end transfer all the information gathered during the charging process to the network through the IoT communications protocol MQTT, Message Queuing Telemetry Transport. The latter is enabled in this scheme by the PI MQTT Broker that is in charge to route the publishes of sensors and subscribes.
2. *Network layer:* To support the autonomous decision taken by smart CS and EAV both participates as nodes of the Tangle the distributed storage databases provided by IOTA, that enable to record each payment in function of price fluctuations, nearly in real time Flash Transaction, for transaction among EAVs and CSs.
3. *Services layer:* Looking at services the main one deals with charging services for EAVs and also Data Insight for service providers. For such a reason, the

integration with GPS and AI could allow the service to locate with accuracy the charging station suitable for the car's autonomy necessity. Furthermore, the service application is in charge to make automatic payments for EAV by enabling automatic payments by the IOTA wallet and by closing the payments channel when the payments process is concluded autonomously. The real time data gathering and the huge amounts of them processed enable ML (Machine learning) techniques to process it to and provides analysis and prediction about the charging level and autonomy for the user usual itinerary.

6 Conclusions

In this thesis have been treated the key concepts of the Industry 4.0 technologies and its European diffusion with a focus on Italy. Thanks to the introduction of the "Industria 4.0" plan it has been possible to put under scrutiny the actual degree of adoption of new Industry 4.0 technologies and the degree of knowledge with regards to its pillars by carrying out a survey in the Piedmont Region. Further the survey concentrated its attention over the introduction of an innovative tech trend, within Industry 4.0, namely the Digital Twin.
During the survey it has been possible to elicit which are the expected components of the Digital Twin by the definition of the main products and business requirements,

DIGITAL TWIN RANKING RESULT	
Real time information of business line	1°
Predictive and preventive maintenance	1°
Predictive analysis for single commission	2°
Automatic ISO standard conformity	2°
Customer information sharing	3°
Blockchain over working activities	3°
Real time information about employees	4°
Data in the Cloud	4°
Mathematical-Statistical simulation	4°
Sharing information with suppliers	5°

Figure 59:Ranking of Digital Twin implementation's proposal (selected sample)

The real time information attracts the firm's interviewed as well as predictive maintenance, predictive and preventive analysis for single commission and automatic ISO standards conformity. The explanation of this findings could be attributed to their operational essence that could lead to the practical improvements in the day by day production. This sounds reasonable because of the manufacturing natures of the interviewed firms in the sample. But surprisingly, just thereafter the top level of the rankings, the most appreciated implementation proposals regards the information sharing both with suppliers and customers. At first sight, it could resemble that the remaining voices of the list are uncorrelated but looking deeply it is possible to grasp suggestions about the possible implementation solutions offered for instance by the blockchain solution.

Nevertheless, the feedbacks received about potential adoption of the Digital Twin and its enabling technologies put in evidence the DT immaturity. More than half of the respondents of the sample analyzed, as shown in Figure 48, possess still scarce intentions to adopt the DT. Due to the high-tech content and its complexity the DT is not emerging for SME which to implement it have to support the costs without having enough internal know-how to fully deploy its potentials. As proved in chapter 1, even authorities through Industria 4.0 plan, revised in the Finance Act of 2019, has introduced new form of incentives, that target training economic support for firm under form of subsidy and cultural awareness about Industry 4.0.

In addition, the lack of a communication’s standard between already purchased machinery to be interconnected and new innovative technologies represent a further barrier to the adoption of DT. As matter of fact integration and interoperability between different systems increase the complexity to the introduction of DT.

Despite of all, some exceptions to the portray depicted emerged during the survey: a particular real case positively responds to the expected cultural level foreseen to identify a virtuous firm about the Industry 4.0 precepts defined, discussed in Chapter 4. A deeper analysis of the company has led to an insight that regards its innovative approach, not only in the technology’s adopted but even in the its organizational constitution. As matter of fact, the firm is a member of a network of business, that for its nature fits with the new concepts of business models applied and enabled by the new ICT technologies of Industry 4.0 that facilitates the sharing of information. By analyzing the business network into the perspective of the fourth industrial revolution and the technologies implemented to feed its new enabled design, a parallel with the concept of sharing economy has led to the conclusion that most of the technologies foreseen could enable M2M communications protocols as standard.

For such a reason, it is possible to think about M2M economies based on the logic of sharing economy as innovative potential solution. The sharing economy supported and implemented by the new technologies of Digital Twin, Blockchain and IoT ensures each firm composing the network to efficiently exploit the purchased assets at its full potential. A new ecosystem where each partner can exchange, with automatic micropayments, bi-directional supply of resources opens new scenario and improvements to the supply chain design and innovative business models, proposed in Chapter 5, and even completely brand new one not yet discovered.

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Questionario Industria 4.0 & Digital Twin

Questionario Industria 4.0 & Digital Twin

Il presente questionario si inserisce all'interno della collaborazione tra il Centro ICT for City Logistics and Enterprises (ICELab@Polito) ed il tessuto delle PMI.

ICELab@Polito è un laboratorio congiunto Politecnico di Torino e Istituto Superiore Mario Boella e mira a farsi promotore di azioni di ricerca (sia pura sia applicata) per la creazione di soluzioni ICT-based per la gestione della città, focalizzandosi in particolare sull'integrazione delle attività industriali nella e per la città e nella progettazione di sistemi intelligenti per la gestione del traffico merci e persone.

Esso è composto da 6 sezioni:

1. Identificazione dell'Azienda rispondente;
2. Livello di conoscenza dei concetti afferenti al paradigma Industria 4.0;
3. Livello effettivo di implementazione dei concetti di Industria 4.0 in Azienda;
4. Livello di conoscenza del paradigma Digital Twin per l'Industria 4.0;
5. Suggerimenti e spunti al fine di migliorare le indagini future;
6. Recapiti dell'Azienda rispondente nel caso si desiderasse essere ricontattati per ulteriori indagini o per la condivisione di informazioni.

Il contributo della Sua Azienda è fondamentale per comprendere quanto Industria 4.0 sia realmente conosciuta in Italia, se siano già stati mossi i primi passi in questa direzione o se siano state riscontrate difficoltà nella sua implementazione e se i benefici attesi ed un generale clima di fiducia ed ottimismo superino le perplessità e le minacce potenziali insite nei grandi cambiamenti che il paradigma propone.

Ci sono 47 domande all'interno di questa indagine.

INFORMAZIONI AZIENDA RISPONDENTE

1 [1]Nome dell' Azienda rispondente: *

Scrivi le tue risposte qui:

2 [2]Posizione del rispondente nell'organigramma aziendale: *

Scrivi le tue risposte qui:

3 [3]Settore di appartenenza dell'Azienda: *

Scegli **solo una** delle seguenti:

- Edilizia
- Consulenza
- Elettronica
- Education and Entertainment
- Utilities (energia, gas, acqua)
- Automotive
- Logistica, trasporti e stoccaggio
- Metalmeccanico
- Farmaceutico, sanitario, bio-tech
- Chimica e materiali
- ICT
- Tessile
- Food and Beverage
- Commercio e finanza
- Altro

4 [4]L'azienda è attiva nell'ambito dei servizi o della manifattura? *

Scegli **solo una** delle seguenti:

- ○ Servizi
- ○ Manifattura
- ○ Altro [ ]

5 [5]Dimensione aziendale (numero di dipendenti) : *

Scegli **solo una** delle seguenti:

- ○ Minore di 10
- ○ Compreso tra 10 e 50
- ○ Compreso tra 50 e 250
- ○ Maggiore di 250

6 [6]Mercati serviti: *

Scegli **tutte** le corrispondenti:

- ☐ Nazionali
- ☐ Internazionali

7 [7]Anno di fondazione: *

Scrivi le tue risposte qui:

[ ]

8 [8]Fatturato (espresso in milioni di euro): *

Scegli **solo una** delle seguenti:

- ○ Minore a 0,5
- ○ Compreso tra 0,5 e 2
- ○ Compreso tra 2 e 10
- ○ Compreso tra 10 e 50
- ○ Maggiore di 50

9 [9]Vende in modo diretto o su commessa? *

Scegli **solo una** delle seguenti:

- ○ Vendita diretta
- ○ Per commessa

10 [10]

Ha 1 o più fornitori principali(almeno il 30% delle materie prime/semilavorati) ?

*****

Scegli **solo una** delle seguenti:

- ○ Sì
- ○ No

11 [10.a]Quanti fornitori principali ha ? *

Rispondi solo se le seguenti condizioni sono rispettate:
° ((**10.NAOK** == "Y"))

Scegli **solo una** delle seguenti:

- 1-3
- 3-10
- 10-20
- >20

12 [12]All'incirca quanta % del fatturato dipende dai suoi clienti chiave ?

Scegli **solo una** delle seguenti:

- Minore del 25%
- Compreso tra 25% e 50%
- Compreso tra 50% e 75%
- Maggiore di 75%

13 [11]Il suo cliente principale in quale mercato si identifica fra i seguenti: *

Scegli **tutte** le corrispondenti:

- PMI
- Grande Impresa
- Vendita al dettaglio

14 [13]Quale quota di mercato detiene l'azienda a livello nazionale? *

Scegli **solo una** delle seguenti:

- Meno del 5%
- Dal 5% al 10%
- Dal 10% al 20%
- Dal 20% al 30%
- Dal 30% al 50%
- Più del 50%
- Non sa/Non risponde

15 [14]Gli ordini sono soggetti a picchi o fenomeni di stagionalità? *

Scegli **solo una** delle seguenti:

- Si verificano picchi di domanda imprevisti
- Si verificano picchi di domanda stagionali
- Non si verificano picchi di domanda o fenomeni di stagionalità
- Non sa/Non risponde

16 [15]In che modo l'azienda affronta questi picchi o aumenti stagionali degli ordini? *

Rispondi solo se le seguenti condizioni sono rispettate:
° ((**14.NAOK** == "A1" or **14.NAOK** == "A2"))

Scegli **solo una** delle seguenti:

- Si utilizzano margini della capacità produttiva (la capacità produttiva non è solitamente utilizzata al 100%)
- Si aumenta la capacità produttiva (straordinari, inserimento di forza lavoro stagionale, lavoro su più turni, lavoro nei giorni festivi)
- Si esternalizza parte della produzione
- Non sa/Non risponde

17 [16]L’azienda ha mai partecipato ad iniziative sullo sviluppo tecnologico ed innovazione (quali bandi, progetti, finanziamenti ecc.)? *

Scegli **solo una** delle seguenti:

- ○ Sì
- ○ No
- ○ Non so

LIVELLO DI CONOSCENZA

18 [1]Ha mai sentito parlare di Industria 4.0? *

Scegli **solo una** delle seguenti:

- ○ Sì
- ○ No

19 [1.a]Dove ne ha sentito parlare? *

Rispondi solo se le seguenti condizioni sono rispettate:
° ((**1.NAOK** == "A1"))

Scegli **tutte** le corrispondenti:

- ☐ Riviste scientifiche
- ☐ Seminari/conferenze/fiere
- ☐ Passaparola di settore
- ☐ Web
- ☐ Non ricordo
- ☐ Altro: ____________

20 [2]Indichi per ciascuna delle seguenti tecnologie il suo livello di conoscenza: *

Scegli la risposta appropriata per ciascun item:

	Molto basso	Basso	Medio	Alto	Molto alto
Cloud	○	○	○	○	○
Internet of Things	○	○	○	○	○
Sistemi Ciberfisici (CPS,Cyberphysical Systems)	○	○	○	○	○
Sistemi di sicurezza cibernetica (Cybersecurity Systems)	○	○	○	○	○
Stampa 3D, Additive Manufacturing	○	○	○	○	○
Sensori smart	○	○	○	○	○
Big Data Analytics	○	○	○	○	○
Realtà virtuale	○	○	○	○	○
Robotica e intelligenza artificiale	○	○	○	○	○
Wearable e dispositivi smart	○	○	○	○	○

Internet of Things: è un network di prodotti fisici integrati con componenti elettronici, software e sensori capaci di connettersi alla rete, in modo da poter raccogliere e scambiare dati.

***I Cyber-Physical* Systems**: sono tecnologie che fondono il mondo fisico con quello virtuale, ossia macchine e componenti fisici connessi e dotati di software e capacità computazionali.

I Cybersecurity Systems: sono quelle tecnologie che permettono alle imprese di proteggersi da possibili attacchi cibernetici ai propri sistemi ciberfisici tra cui crittografia e blockchain.

Stampa 3D: Per stampa 3D si intende la realizzazione di oggetti tridimensionali, mediante produzione additiva, partendo da un modello 3D.

Big Data Analytics: Per Big Data Analytics si intendono quelle tecnologie che permettono la raccolta, il processamento e l'analisi di grandi moli di dati.

Realta virtuale: La realtà virtuale fa riferimento a quei dispositivi che permettono di generare una realtà simulata e l'interazione in un ambiente virtuale.

Wearable: I wearable sono dispositivi indossabili dotati di molteplici funzionalità, tra cui si annoverano smartwatch e smart glasses.

21 [3]È a conoscenza di bandi/finanziamenti erogati da enti/fondi a favore dello sviluppo tecnologico e dell'implementazione delle tecnologie coerenti con il paradigma di Industria 4.0? *

Scegli **solo una** delle seguenti:

- ○ Sì
- ○ No

22 [3.a]Di quali è a conoscenza? *

Rispondi solo se le seguenti condizioni sono rispettate:
° ((**3.NAOK** == "A1"))

Scrivi le tue risposte qui:

____

23 [3.b]È riuscito ad usufruire degli incentivi proposti dal piano Calenda? *

Rispondi solo se le seguenti condizioni sono rispettate:
° ((**3.NAOK** == "A1"))

Scegli **solo una** delle seguenti:

- ◯ Sì
- ◯ No

24 [4]È a conoscenza delle normative europee sulla gestione dati GDPR ? *

Scegli **solo una** delle seguenti:

- ◯ Sì
- ◯ No

25 [5]Quali fra le seguenti azioni ha attuato o quali intende mettere in atto per adeguarsi alla normativa

Rispondi solo se le seguenti condizioni sono rispettate:
° ((**4.NAOK** == "Y"))

Scegli **tutte** le corrispondenti:

- ☐ Fornire strumenti di consenso aggiornati con le nuove normative
- ☐ Informare l'utente/cliente riguardo alle finalità del trattamento dei suoi dati personali e la profilazione alla quale sarà soggetto
- ☐ Assumere un DPO (Data Protection Officer, responsabile dati)
- ☐ Monitorare costantemente la gestione agli accessi e i permessi ai dati
- ☐ Garantire un alto livello di protezione e sicurezza per i dati che varcano i confini nazionali
- ☐ Gestire un archivio di dati sensibili (carte di credito, informazioni sulla salute) in un luogo molto sicuro.

26 [6]Nel concetto di industria 4.0 spesso si fa riferimento a servizi esterni che coinvolgono l'utilizzo di dati della sua azienda. Considera la possibilità di permettere l'accesso a questi dati? *

Scegli **solo una** delle seguenti:

- ◯ Si
- ◯ No
- ◯ In Parte

27 [6.a]Per quali motivi ? *

Rispondi solo se le seguenti condizioni sono rispettate:
° ((**6.NAOK** == "2"))

Scegli **tutte** le corrispondenti:

- ☐ Scarsa sicurezza dei dati
- ☐ Diffidenza nei confronti di chi li gestisce
- ☐ I dati sono personali dell'azienda e solo chi ne fa parte può averne accesso
- ☐ Non vedo vantaggi economici nella condivisione di questi

28 [6.b.1]Per le seguenti tipologie di dato quale grado di accessibilità da esterni o condivisione reputa più adeguato? *

Rispondi solo se le seguenti condizioni sono rispettate:
° ((**6.NAOK** == "3"))

Scegli la risposta appropriata per ciascun item:

	Inaccessibile	Parzialmente accessibile su richiesta	Totalmente accessibile su richiesta	Libero accesso
Dati legati a specifiche di produzione	◯	◯	◯	◯
Dati legati alla logistica	◯	◯	◯	◯
Dati di monitoraggio del flusso di produzione	◯	◯	◯	◯
Dati sensibili di profilo cliente	◯	◯	◯	◯

29 [7]È a conoscenza di criteri di sicurezza riguardo i dati informatici e alle tematiche in ambito di Cybersecurity?

Scegli **solo una** delle seguenti:

- Sì
- No

30 [8]Quali fra queste tecniche di sicurezza informatica sono state adottate ? *

Rispondi solo se le seguenti condizioni sono rispettate:
° ((**7.NAOK** == "Y"))

Scegli **tutte** le corrispondenti:

- Reti aziendali chiuse con sistemi antintrusione e firewall
- Server interni aziendali con accessi controllati con funzioni di backup custoditi in ambienti sicuri
- Formazione del personale in ambito Cybersecurity (ad esempio: formare il dipendente riguardo a come accedere ai dati aziendali secondo criteri prestabiliti)
- Nessuna delle soluzioni indicate precedentemente corrisponde al mio attuale livello di protezione, che invece consiste in ::

31 [9]È a conoscenza delle soluzioni Cloud, come ad esempio SaS (Software as a Service, esempi: Dropbox, Google Drive)? *

Scegli **solo una** delle seguenti:

- Sì
- No

32 [9.a]Adotta soluzioni Cloud attualmente per le attività che coinvolgono l'azienda? *

Rispondi solo se le seguenti condizioni sono rispettate:
° ((**9.NAOK** == "Y"))

Scegli **solo una** delle seguenti:

- Sì
- No

33 [10]In riferimento alle risposte date alle domande precedenti, in relazione alla gestione dei dati dell'azienda, sarebbe disponibile alla condivisione di dati per servizi cloud ? *

Scegli **solo una** delle seguenti:

- Si
- No
- Non so

34 [11]Considera la sicurezza informatica offerta dai gestori di Servizi Cloud (come servizi di salvataggio di dati) più vulnerabile rispetto ai sistemi di protezione implementati in azienda (server in azienda)? *

Rispondi solo se le seguenti condizioni sono rispettate:
° ((**7.NAOK** == "Y") and (**9.NAOK** == "Y"))

Scegli **solo una** delle seguenti:

- Sì
- No

IMPLEMENTAZIONE EFFETTIVA CONCETTI DI INDUSTRIA 4.0

35 [1]Quali, tra le seguenti attività, ritiene importanti per il suo business? *

Scegli **tutte** le corrispondenti:

- ☐ Manutenzione preventiva e predittiva
- ☐ Uso di Robot collaborativi (COBOT)
- ☐ Automatizzazione dei processi produttivi
- ☐ Sostenibilità ambientale e risparmio energetico
- ☐ Formazione sul campo dei dipendenti su utilizzo e gestione dei nuovi strumenti digitali
- ☐ Attrarre risorse esperte di meccatronica integrante meccanica,elettronica,informatica e controlli automatici
- ☐ Attrarre manager per governare innovazione e digitalizzazione
- ☐ Raccolta e analisi di dati sulle attività in essere
- ☐ Integrazione orizzontale (cioè espansione delle attività dell'impresa a prodotti, processi, know-how affini alla filiera già esistente) tramite protocolli standard di comunicazione
- ☐ Integrazione verticale (cioè internalizzazione delle fasi a monte/a valle della filiera in cui già opera l'impresa) tramite protocolli standard di comunicazione
- ☐ Progettazione dei prodotti assistita da calcolatore/strumenti di simulazione
- ☐ Produzione di piccoli lotti fortemente customizzati
- ☐ Flessibilità organizzativa e predisposizione al cambiamento
- ☐ Offerta di servizi in supporto ai prodotti fisici
- ☐ Allocazione di risorse ad attività di ricerca e sviluppo
- ☐ Formalizzazione di un approccio strategico per incentivare l'innovazione

36 [2]Indichi dalla seguente lista di tecnologie il grado di <u>effettiva implementazione</u> di ciascuna di esse, facendo riferimento alla relativa definizione: *

Scegli la risposta appropriata per ciascun item:

	Non di interesse	Di interesse, ma non ancora implementata	È nei piani	Implementata
Dati o software in Cloud	○	○	○	○
Internet of Things	○	○	○	○
Sistemi ciberfisici (Cyber-Physical Systems, CPSs)	○	○	○	○
Sistemi di sicurezza cibernetica (Cybersecurity Systems)	○	○	○	○
Stampa 3D, additive manufacturing	○	○	○	○
Sensori smart	○	○	○	○
Big Data Analytics	○	○	○	○
Realtà virtuale	○	○	○	○
Robotica ed intelligenza artificiale	○	○	○	○
Wearable e dispositivi smart	○	○	○	○

Internet of Things: è un network di prodotti fisici integrati con componenti elettronici, software e sensori capaci di connettersi alla rete, in modo da poter raccogliere e scambiare dati.

***I Cyber-Physical* Systems**: sono tecnologie che fondono il mondo fisico con quello virtuale, ossia macchine e componenti fisici connessi e dotati di software e capacità computazionali.

I Cybersecurity Systems: sono quelle tecnologie che permettono alle imprese di proteggersi da possibili attacchi cibernetici ai propri sistemi ciberfisici tra cui crittografia e blockchain.

Stampa 3D: Per stampa 3D si intende la realizzazione di oggetti tridimensionali, mediante produzione additiva, partendo da un modello 3D.

Big Data Analytics: Per Big Data Analytics si intendono quelle tecnologie che permettono la raccolta, il processamento e l'analisi di grandi moli di dati.

Realta virtuale: La realtà virtuale fa riferimento a quei dispositivi che permettono di generare una realtà simulata e l'interazione in un ambiente virtuale.

Wearable: I wearable sono dispositivi indossabili dotati di molteplici funzionalità, tra cui si annoverano smartwatch e smart glasses.

37 [3]Indichi i <u>benefici attesi</u> dall'implementazione delle tecnologie già in uso e di quelle che si è predisposti ad adottare:

Scegli **tutte** le corrispondenti:

- ☐ Aumento di produttività
- ☐ Aumento di efficienza
- ☐ Aumento della qualità dei prodotti/processi
- ☐ Riduzione delle tempistiche (es. time-to-market,set-up)
- ☐ Aumento di affidabilità dei prodotti/processi
- ☐ Aumento della sicurezza dei lavoratori
- ☐ Riduzione dei costi
- ☐ Aumento dei profitti
- ☐ Livellamento dei carichi energetici e riduzione utilizzo di energia
- ☐ Maggiore soddisfazione dei consumatori
- ☐ Realizzazione di prodotti customizzati in piccoli lotti
- ☐ Aumento della trasparenza nelle attività svolte dai vari attori della filiera
- ☐ Interoperabilità tra i vari attori, sincronizzazione e scambio di informazioni
- ☐ Miglioramento del processo di controllo del ciclo di vita del prodotto
- ☐ Miglioramento del processo decisionale
- ☐ Altro: ______

38 [4]Esiste in Azienda un piano di <u>azione strategica formalizzato</u> al fine di favorire l'innovazione? *

Scegli **solo una** delle seguenti:

- ○ Per nulla
- ○ E' in fase di sviluppo
- ○ E' attualmente in atto

DIGITAL TWIN

Recentemente nel contesto di **Industria 4.0**, si inseriscono nuove soluzione software che permettono di replicare macchinari, in *tempo reale*, fornendone una copia digitale il più fedele possibile. Queste soluzioni sono implementabili ex novo con nuovi macchinari o con macchinari preesistenti ammodernati a scopo di re-fitting digitale. In letteratura questa nuova tecnologia acquisisce il nome di **Digital twin**. Le implementazioni del software **Digital Twin** attualmente si inquadrano nelle attività di monitoraggio della produzione e di manutenzione del macchinario. Nonostante queste siano le principali caratteristiche che vengono riconosciute nel **Digital Twin**, il suo reale valore aggiunto sembra convergere nella costituzione di un *"Database Macchina"* che lasci libero sfogo a nuove soluzioni di business specialmente legate all'analisi dei dati a scopo predittivo e di simulazione virtuale.

39 [1]Sulla base della descrizione sopra, ha mai sentito parlare di Digital Twin? *

Scegli **solo una** delle seguenti:

- ○ Sì
- ○ No

40 [2]Reputa utile, per la sua attività, la possibilità di avere informazioni in tempo reale sullo stato dei propri macchinari, dell'intera linea produttiva e sulle attività svolte dai dipendenti? *

Scegli **solo una** delle seguenti:

- ○ Sì
- ○ No

41 [3]Quale importanza dà alle seguenti implementazioni? *

Rispondi solo se le seguenti condizioni sono rispettate:
° ((**2.NAOK** == "Y"))

Scegli la risposta appropriata per ciascun item:

	Per nulla importante	Poco importante	Mediamente importante	Importante	Molto importante	Non applicabile
Informazioni in tempo reale sullo stato dei macchinari o dell'intera linea produttiva	○	○	○	○	○	○
Informazioni in tempo reale sulle attività svolte dai dipendenti	○	○	○	○	○	○
Dati raccolti in cloud e consultabili da qualsiasi computer connesso alla rete ed eventualmente da smartphone	○	○	○	○	○	○
Possibilità di sfruttare i dati raccolti in tempo reale per effettuare delle simulazioni matematico-statistiche sui processi produttivi col fine di efficientare la produzione e le risorse impiegate.	○	○	○	○	○	○
Condividere alcune delle informazioni raccolte con i suoi fornitori al fine di schedulare meglio le proprie attività produttive	○	○	○	○	○	○
Condividere in modo automatico alcune delle informazioni raccolte (ad esempio stato dettagliato di produzione di una commessa) con i suoi clienti al fine di rendere più trasparenti i rapporti di business	○	○	○	○	○	○
Possibilità di registrare e certificare in modo automatico/semiautomatico tutte le lavorazioni o attività necessarie alla produzione ed eventualmente previste dal contratto	○	○	○	○	○	○
Possibilità di ricevere suggerimenti e indicazioni automatici riguardo la conformità dei processi/lavorazioni rispetto alle norme ISO di settore	○	○	○	○	○	○
Analisi predittive, sui dati raccolti, volte a segnalare la data futura di guasto dei macchinari	○	○	○	○	○	○
Analisi predittive, sui dati raccolti, volte a segnalare l'impossibilità di consegnare una commessa in tempo	○	○	○	○	○	○

42 [5]Tutti i benefici del Digital Twin sono ad oggi oggetto di incentivi statali riguardo l'Industria 4.0, sarebbe disposto ad investire su tali implementazioni?: *

Scegli **solo una** delle seguenti:

- ○ Si, sono interessato alla tecnologia e prevedo entro un breve periodo di implementarlo
- ○ Si, sono interessato ma preferirei vedere i risultati di casi d'uso che lo implementano
- ○ No, non reputo sia una tecnologia utile

43 [8]Negli ultimi 3 anni ha effettuato investimenti in Industria 4.0? *

Scegli **solo una** delle seguenti:

- Sì
- No

44 [8.a]Ha avuto dei miglioramenti effettivi, anche in termini di aumento fatturato ? *

Rispondi solo se le seguenti condizioni sono rispettate:
° ((**8.NAOK** == "Y"))

Scegli **solo una** delle seguenti:

- Sì
- No

45 [9]Se ha effettuato o pensa di effettuare investimenti sull'Industria 4.0, in che lasso di tempo si aspetta di averne un ritorno economico? *

Scegli **solo una** delle seguenti:

- Breve Periodo
- Medio Periodo
- Lungo Periodo

SUGGERIMENTI

46 [1]Se c'è qualche aspetto che giudica significativo e che non è stato trattato in questo questionario lo indichi di seguito:

Scrivi le tue risposte qui:

RECAPITI

47 [1]Si fornisca un recapito se si desidera essere contattati in futuro per ulteriori indagini o per ricevere i risultati della nostra ricerca:

Scrivi le tue risposte qui:

Grazie per il tempo speso a favore della conoscenza!
1970.01.01 – 01:00

Invia il tuo questionario.
Grazie per aver completato il questionario.