LUISS

Department of Economics and Finance

Bachelor Thesis in Entrepreneurship, Innovation and Technology

Industry 4.0 in Italy; example of application: prepackaged concrete production plants

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“Innovating means opening mind, culture, organization and tools to other areas and other business disciplines”

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INDUSTRY 4.0 IN ITALY; EXAMPLE OF APPLICATION: PREPACKAGED CONCRETE PRODUCTION PLANTS

INTRODUCTION

The fourth industrial revolution is occurring, and from it derivates the Industry 4.0. This term indicates the automation and digitalization of firms, changing their processes, organization and methodologies of working. This obviously creates some risks within the firm, but most importantly, advantages that, if well exploited, create new opportunities. In addition, it allows the firm to increase its efficiency since in the smart work place physical and mental resources are employed to obtain a process improvement and are less employed in repetitive operations. This thesis shows the application of industry 4.0 in the concrete production process.

In addition to the important advantages listed above, the focus on concrete highlights another potential of automation since it also favors the use of inert aggregates material from construction and demolition, thanks to the automized plant's ability to automatically adapt itself to the use of a higher number of materials with different performances. Moreover, the automized plant grants higher security on its final application.

The first chapter defines the Industry 4.0 concept, starting from the evolution of the industry until now. Then the timeline of the Industry 4.0 is shown, reporting how different governments of different countries are supporting the innovation. In particular there is an in-depth look at the Italian Piano Nazionale. The spread and market values of Italian firms 4.0 are reported. In order to analyze which sectors are more advanced in the field and if any correlation exists between a firm's characteristics and the propensity to digitalization, a study of industries' characteristics is included. Since this analysis shows a gap between SMEs and big enterprises, it is fundamental also to analyze how the Italian regulation evolved over the years to reduce differences among these firms.

The second chapter provides an example of application of the industry 4.0 paradigm in the concrete sector. It defines concrete and its production process (dosage and mixing), in order to better understand the implementation of the 4.0 systems in production plants. Before presenting the Concrete 4.0 project, the regulation's requirements in compliance with the 4.0 paradigm are listed. Subsequently, how to access benefits through the certification and self-certification and how calculate the R&D tax credit benefit is explained. In addition, the section also gives practical examples of how the firm can meets those requisites. The implementation scheme is described, with all the technologies applied in the project: PLC, IoT, SQL, POWER BI, app, data warehouse and IP. Finally, the automation of the plant is explained, including how the plant works in compliance with 4.0 requisites in each phase of the process.

In the third chapter a real case is presented in order to better understand the advantages of digitalization. Some reports obtained through Power BI are also explained and shown.

From this analysis emerges the need of innovation in some sectors more than in others. In the case of the construction economic sector, and in particular in concrete production, the need is not only linked to a better efficiency and to a cost minimization, but a better and real-time analysis permits the reduction of damages in its later applications.

1.AN OVWERVIEW OF INDUSTRY 4.0

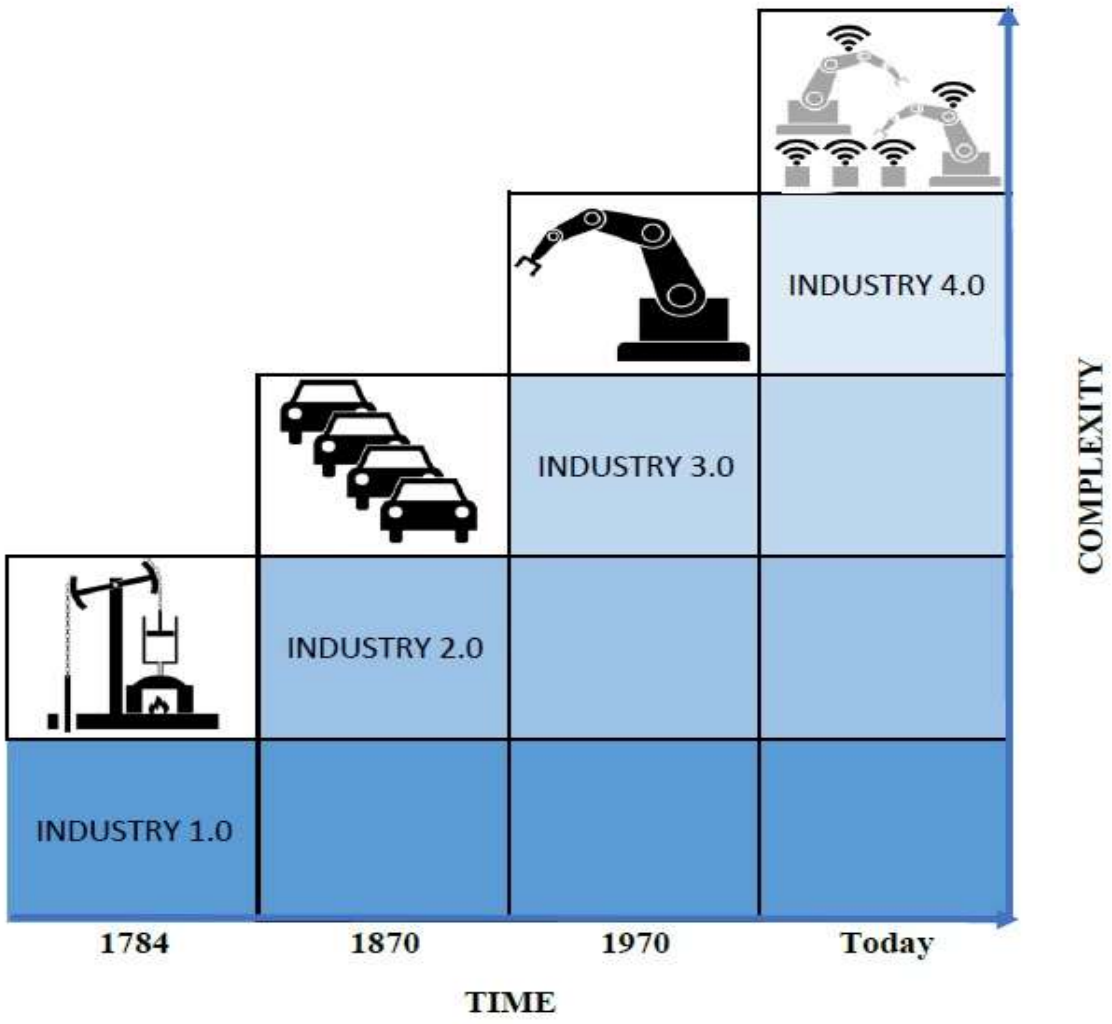
1.1 WHAT IS INDUSTRY 4.0

In this chapter the industrial evolution is described, analyzing impacts of industrial revolutions in the market, within the firm and the change of the human-machinery relationship.

Industry 4.0 is a digitalization process, which uses the implementation of a mix of technologies, that have big impacts on the firm and its processes. The potential efficiencies and advantages of digitalization are explained, thus illustrating the reasons why a firm should undertake this path.

Since the industry 4.0 paradigm is spreading around the world, an analysis of different focuses and different governments' support is provided. In particular, the Italian Piano Nazionale Industria 4.0 stimulates the transition providing many funds and tax benefits.

1.1.1 The evolution of Industry



1784 – Industry 1.0

Market: capitalism affirmation, bigger consumption

Technology: Use of machines powered by mechanical energy, invention of the steam engine that allows abandoning mills

Impact: greater speed and power

Organization: work division, worker class and entrepreneur figure arise.

Human roles and skills: The job is bounded to the machinery. Human biological rhythms are adapted to those of the machinery. Workers are heterogeneous, no special skills required.

1870 – Industry 2.0

Market: Mass market, big quantities sold at a low price, Oligopoly

Technology: Introduction of electricity, chemicals products and oil

Impact: the assembly line and inaugurating the era of mass production

Organization: Production phases are decomposed, interconnected and synchronized (Taylorism: reduces production costs and times)

Human roles and skills: Human job depends on the assembly chain

1970 – Industry 3.0

Market: Globalization

Technology: Introduction of industrial robots and computers, use of electronics and IT

Impact: flexible and varies production, better quality production, real time control

Organization: Industries do not produce everything in one factory, differentiation of production phases and delocalization. The infrastructures are diversified and new processes which diversify and facilitate the work of the people are started

Human roles and skills: Human work sometimes is substituted with a machinery. Knowledge and skills are required.

Industry 4.0

The global interconnection is growing continuously and this leads to a complete transformation of the manufacturing process, which represents the fourth industrial revolution: Industry 4.0. It regards not only the traditional industrial automation but also a form of digital integration of all its components. It is important for firms to understand the potential of the industrial digitalization to exploit its benefits, such as being more competitive on the market, creating a stronger team, being more attractive to younger workers and anticipating problems.

The transformation of production is possible thanks to the application of technologies such as Big data and analytics, advanced robotics, Cloud and Cloud computing, cyber-security, IoT, additive manufacturing, augmented reality and wearable technology.

1.1.2 Definition of Industry 4.0

Industry 4.0[1] is a process of manufacturing digitalization, which, when combined with a mix of technology, automation, information, connection, access to real-time data and programming, renovates the value chain, changes the way in which firms work and the nature of its organization. This revolutionizes the way the entire business of a company operates and grows. Moreover, it is a strategic way to innovate exploiting the incentives given by the government.

Internet communication and all the characteristics of Industry 4.0 listed above are spreading in firms, making the production process easier and more adaptable to market needs. This innovation is happening not only at the technological level, but it has also changed skills required by employees, who need to be specialized in order to deal with digital technologies.

The aim of industry 4.0 is to create a more holistic and better-connected ecosystem in manufacturing and supply chain management. It is an interesting argument for any kind of company because even though every company is organized and operate differently, they all have the common need for connectedness and access to real-time insight of processes, partners, products, and people. In addition, it allows for better collaboration and access between departments, partners, vendors, product, and people. Industry 4.0 empowers business owners

[1] Laura Zanotti, Industria 4.0: Cos'è, come fare ed esempi concreti di smart manufacturing, 27 Feb 2017, available at https://www.internet4things.it/industry-4-0/

to better control and understand every aspect of their operation and allows them access to instant data to boost productivity, improve processes, and stimulate growth.

The focus on digitalization is possible thanks to the Internet of Things (IoT), access to real-time data, and the introduction of cyber- manufacturing. It brings firms into a new dimension called bimodal, because it includes both the physical and virtual parts of the business. This in turn results in achieving a better collaboration across all the internal and external activities, which will be translated into gaining a higher level of efficiency.

A collective, shared and collaborative management of information into a business, new cloud, and mobility logic is the result of these new production models, always more automized and interconnected as well as smart, communicating assets and products and trackable processes. The focus on industrial Internet, new generation software and Big Data Management brings the production to a new level: mass personalization.

The continuous evolution of technology associated with the use of Artificial Intelligence and all digital drifts, including Blockchain, diversify the application of 4.0 to multiple levels and operational fields. Hence, the solutions that 4.0 offers are many and it is a challenge to organize them coordinately and a broad vision is crucial. The common factor is the integration of processes which leads firms to create new complex production and the business development process.

Experts of Boston Consulting and McKinsey define the so-called Smart Factory[2], dividing the technological cluster into three levels:

1. Smart Production: consists in the interaction among all the assets of production supporting also the collaboration among humans thanks to new productive technologies
2. Smart Service: new generation governance of informatics and technical infrastructure helps manage systems exploiting high integration logic among all the actors of the supply chain
3. Smart energy: new power systems' attention to monitoring energy consumption, making infrastructures more efficient, cheaper and more ecological.

[2] Laura Zanotti, Industria 4.0: storia, significato ed evoluzioni tecnologiche a vantaggio del business. 01 Mar 2019, available at https://www.digital4.biz/executive/industria-40-storia-significato-ed-evoluzioni-tecnologiche-a-vantaggio-del-business/

In fact, technological innovation makes production and management processes better, smarter, faster and more efficient.

Among the technological solutions of smart factory, for instance, there is the development of additive manufacturing. These are systems that allow a low-cost production of prototypes, advanced production systems, such as collaborative robots and automized plants for material handling, and virtual simulation systems that also use augmented reality.

Analysts of Industry 4.0 of the Osservatorio del Politecnico di Milano, analyze all the smart technologies, focusing on which on how they are exploited to create additional value, reduce inefficiency, better integrate the resources and improve the capability of planning and reacting.

They defined three sectors in which digital technologies are changing the Smart manufacturing models:

1. Smart Lifecycle Management: this includes the entire development process of products including the management of its life-cycle
2. Smart Supply Chain: this concerns the planning of physical and financial flows in the logic-productive system
3. Smart Factory: this includes the infrastructure and services governance; production, internal and external logistic, maintenance, quality, safety.

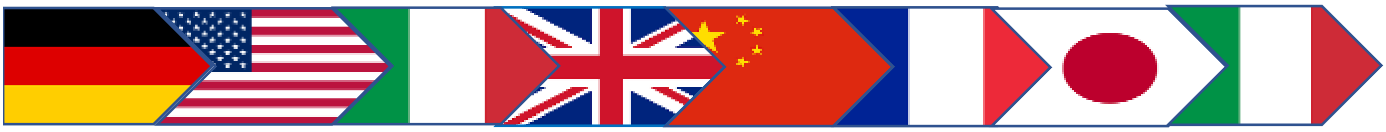
In Smart Manufacturing plants, employees, raw materials and end products will be provided with an identification sensor that will detect in real time their location, status, and activity, and simultaneously analyze this data to improve the production capability, efficiency, security. Moreover, the whole factory is connected to the logistic-productive system and to clients through cloud platforms. It is useful for instance, for good maintenance and to predict problems in processes.

According to the analysts of the Politecnico, the logic service associated with the cloud manufacturing will evolve into a new model called Manufacturing as a Service.

The core of the fourth industrial revolution is the better interconnection at the horizontal and vertical level. This translates into increased efficiency thanks to better working conditions, higher productive quality of plants, lower energy costs, which will result in an offer always able to meet the demand.

1.1.3 Industry 4.0 around the world

The timeline of industry 4.0 spread around the world is:



2006: High-tech strategy 2012: Industry 4.0	2011: Advanced Manufacturing partnership 2015: Manufacturing USA	2012: Cluster Tecnologico Nazionale Fabbrica Intelligente	2015: Industrial Strategy	2015 2025: Made in China	2015: Industrie du Future	2015: Industrial Vale Chain Initiative	2017: Piano Nazionale Industria 4.0

The fourth industrial revolution[3] could be the starting point to overcoming the financial crisis which began in 2008; but to make it possible European and International Nations must be able to handle the transformation process.

National governments, research and development centres, and universities (at the world level) have been developing intervention initiatives and targeted investments programs to guide firms through the transformation process and make them understand the advantages of development and the implementation of new technologies.

Nations have adopted different political plans. The main reference models are those of Europe and the US, even though, of course, each country has its own action strategy. Both models focus

[3] Luca Franzoni, Massimo Zanardini, Industria 4.0 in Italia e nel mondo I Governi rilanciano il manufatturiero

on the importance of physical cyber for the machines, products and people integration within the firm value chain and within the society.

The European model's aim is to create smart factories to achieve higher efficiency, so it provides a standardized guide for all businesses for the adequate technologies development, more specifically in the optimization of the manufacturing sector. In European countries it is usually possible to identify a public-private partnership between the government and its Ministries and research centres, universities, and economic and entrepreneurial sectors. In addition, it offers research and development tax credits and super-amortization for the purchase of new goods.

Instead, the US model is more concerned with the interaction connection between the product and the final client. To achieve this, the focus is on improving activities regarding services and defining platforms designed to allow interconnection of objects in an adaptable and open manner. The point of reference is the IoT and the use of cloud, sensor and machine-to-machine connections. The objective is to create the "Smart Manufacturing Platform" based on cloud and big data, able to integrate internal and external data and processes of the single plant. In this model the government intervention is reduced and its support is around 1.5 billion dollars.
Even though European government offers a standardized model, each country has a different degree level of the evolution of industry 4.0.

As the timeline shows Germany[4] is the pioneer of the fourth revolution, where the term industry 4.0 was used for the first time. Its objective was to implement a digitalization strategy of national manufacturing to achieve technological transformation within 10-15 years, thus becoming a leader in the field. From the technological point of view, a central role is carried out by the CPS (cyber-physical-system) concept and also the IoT.

The "Plan d'alliance pour l'Industrie du Futur" was implemented in France to face this phenomenon and to accelerate modernization of firms, by extending the super-amortization and investments. The focus was mainly on additive manufacturing, cyber-security, digitalization on the value chain, including IoT, and energy efficiency solutions. A characteristic of the French

[4] Luciana Maci, Industria 4.0, che cosa succede in Europa e negli Usa, 14 Dec 2016, available at https://www.economyup.it/startup/industria-40-che-cosa-succede-in-europa-e-negli-usa/

approach is also the focus on environmental issues, with concessions for companies that invest in sustainable research and development. Nevertheless, France keeps having gaps in the industrial robotics field, so it had to extend the incentives such as tax credit for research and innovation, investment programs.

In Great Britain, the support, as in Italy, is mainly given by centres specialized in technological knowledge, which make their facilities and skills available aimed at helping during the transition phase. However, Great Britain is still behind in the understanding of the importance of industry 4.0 and also in its implementation. Only 8% of workers of the manufacturing industry is aware of the processes of the fourth revolution and one third of businesses risk losing their competitiveness since they do not invest in the technologies of industry 4.0. What is even more alarming is that many of the firms don't even consider making investments in this area in the future.

Italy has been applying the "Piano Industria 4.0" and the rules for the industrial transformation came into effect in 2017, including tax incentives, support for venture capital, training from schools to universities. The ultimate aim is to encourage companies to adapt and fully adhere to the fourth industrial revolution.

Moreover, the plan offers:10 billion euros to private investments, 11.3 billion for private expenses in research and development and technology 4.0; more than 2,6 billion euros for private investments in early stages. In addition to the European regulation in Italy the hyper-amortization for investment in technological equipment related to Industry 4.0. is recognized.

1.1.4 Piano Nazionale Industria 4.0

The Italian Ministry of economic development (MISE) proposes the industry 4.0 national plan[5] for firms that want to exploit the legal opportunities of the fourth industrial revolution. It comprehends three main guidelines:

1. Operate in a logic neutral technology
2. Intervene with horizontal and not vertical or sectorial actions

[5] Piano Nazionale impresa 4.0. available at https://www.mise.gov.it/index.php/it/industria40

3. Action enabling factors

The MISE rearranged the existing laws to make them compatible with the logistic and new needs associated with industry 4.0 and they created new ones.

The main programs proposed by the "Piano Nazionale Industria 4.0" are: hyper and super-amortization, "Nuova Sabatini", guarantee funds, tax credit for R&D, Innovation agreements, development control, innovative start-ups and SMEs, Patent Box, high specialized competent centres, technological transfer centres and training tax credit.

The purpose of the plan is to support and stimulate the transition to the fourth industrial revolution to make businesses achieve a future competitive advantage, covering different sectors for growth and development. It offers credit to innovative firms who invest, for instance, in new technologies, plants or machinery or in experimental research and development. In addition, it provides services to improve expertise such as training or consulting programs.

Since in Italy there is a high concentration of SMEs and start-ups many programs are solely directed to them, with the objective of accelerating the innovation.

1.2 SPREAD AND MARKET VALUES

The Industry 4.0 in Italy is growing. The degree of digitalization is different based on corporate characteristics, economic sector and size. An analysis of propensity to digitalization is reported, taking into account innovation propensity, a network analysis, use of ITC and capital endowment. At the end five different groups of digitalization profiles are recognized.

1.2.1 Industry 4.0 in Italy

The evolution of industry 4.0 has good forecasts but still, it is only in its early stages. Nowadays, only 8.4% of Italian industries[6] use at least one of the technologies considered as enabling digital transformation by the "Piano Industria 4.0", and 4.7% have planned future investments.

Some technologies have been implemented more than others. Cybersecurity, horizontal integration, and IoT are the investments which are more widespread in small firms, while big

[6] La diffusine delle imprese 4.0 e le politiche. Available at: https://www.mise.gov.it/images/stories/documenti/Rapporto-MiSE-MetI40.pdf

and medium enterprises focus their investments on horizontal and vertical integration and digital security. Those with more complex structures exploit the co-robot, augmented reality and virtual simulation.

The expected growth of the phenomenon spread forecasted is of 9,4% for small enterprises and of 8,2% for medium enterprises. Nevertheless, some companies still have not understood digital technologies' application. Other companies believe these technologies are not applicable to their field, while others find combination of multiple technologies more troublesome. For instance, there are only a few industries that implemented bot IoT and Big Data, while others admitted to using only one of them. In fact, 37.3% of companies 4.0 make use of one technology and only 25.1% make use of two technologies, and more than 60% of bigger companies have a more integrated system of 4.0 technologies.

The application field changes based on the number of technologies used: smaller enterprises, that introduce only up to two technologies, focus on the application of data usage techniques. While bigger enterprises are more concerned with the production phase when more technologies are integrated. Both applications have been implemented in 50% of medium enterprises and in 69.2% of bigger ones.

1.2.2 Pre-requisites

Engaging in the 4.0 path means changing processes, introducing digital technologies able to communicate and share data and information in order to take quick and conscious decisions. This system also allows firms to manage in real-time changes in internal and external environments, therefore guaranteeing higher levels of efficiency.

The previous chapter underlined the importance of the digital transformation to be competitive at the national and international level, but it is also fundamental for analyzing how firms undertake this path. Each firm uses different technologies and has different organization processes, based on the characteristics of the industry and of the business. It implies that before starting the transformation firms are at different levels, and for this reason, some firms will be more ahead than others.

Firms that have certain characteristics will be able to make a quicker transformation. The starting point obviously is that the need for the digital transformation must be recognized at the top level of the firm. And since it will modify the corporate organizational identity, processes, employees' roles, and competencies, the entire organization must be completely committed to it.

One of the most relevant factors that will affect the speed of the transformation is the company's level of IT integration. Low computerized companies (that have low IT integration level), since the initial assumptions are not solid enough, have more difficulties in embracing the 4.0 paradigm, and do not have the possibility to start the transformation process quickly. It is important that companies are modernized and understand properly how to apply the technologies.

In fact, companies where the IT area is an active part of the definition of the corporate strategy focused on the application of new digital technologies, are those more inclined to start the transformation.

Hence, for companies to undertake the 4.0 path, they must first consolidate the 3.0 configuration in order to concentrate on the development of the new paradigm.

The innovation propensity depends mainly on the mindset of the company. Industries that are already 4.0 (8,4%) and those that have planned 4.0 intervention have higher probability to implement the set of technologies used in their processes. While more traditional firms that do not use any 4.0 technologies still have not planned any intervention in the field, and unfortunately this is 89,6% of Italian firms. Since they are not open to innovation, the probability of initiating the industrial transformation in the next years is very low. In fact, traditional companies that have scheduled 4.0 interventions introducing at least three 4.0 technologies within the next three years are only 4.7% of Italian industries.

1.2.3 Propensity to Innovate

It is clear that there is a relation between innovation and digitalization, but is it true for all categories of companies? Innovation effects on performance depend on corporate characteristics, and it implies that not all the firms innovate in the same manner and with the same intensity. By analyzing the Italian industry, the results show that innovation differs among different economic sectors and among different sized firms.

Manufacturing[7] firms are those more involved in the innovation process, but even within the sector the level of innovation varies with the level of competitiveness: electrical, chemical and pharmaceutical are the most innovative sectors, as well as production of electric apparatus, machinery, transport equipment, and the beverage industry. More traditional sectors, such as

[7] Istat, Innovazione, Nuove Tecnologie e Innovazione, Ch. 3, Rapporto sulla competitività dei settori produttivi, 2018. Available at https://www.istat.it/storage/settori-produttivi/2018/Capitolo-3.pdf

leather and clothing, are less propense to innovate even though their innovation investments are increasing. Although innovation in the service sector is decreasing, great propensity to innovate is found in the IT, insurance, and research and development sectors.

Since there is not a unique way to innovate a distinction can be made among:

- Strong innovators
- Product innovators
- Process innovators
- Soft innovators
- Potential innovators

Strong and potential innovators' percentage increases as the size of the firm increases, while the number of soft innovators decreases as the size increases. There is not a clear relationship between the size of the firm and product and process innovation. While from the sectoral point of view manufacturing firms tend to be product innovators while services are soft innovators. The manufacturing sector is very heterogeneous: electrical, motor vehicle, beverage and chemical enterprises are strong innovators; while some activities such as machinery production and electrical apparatus are product innovators. Pharmaceutical, metal and other sectors instead are focused on new technologies and production processes. Finally, potential innovators are more concentrated in electrical, chemical and pharmaceutical sectors.

The process through which companies innovate is linked to their structure: innovation through investments in creative activities is more frequent in bigger firms since smaller ones invest more in material or intangible technologies. Investments in R&D and design are more frequent in strong innovators and in manufacturing sectors, such as electrical, chemical-pharmaceutical, electric and electronic machinery production, which are characterized by a high level of knowledge since innovation is necessary to compete. These activities are also used by product innovators and potential innovators; process innovators acquire know-how from "outside" technologies. As the size of the firms increases the trend to use external collaboration to innovate also increases. Strong innovators and product innovators are those more open to collaborations.

Economic sectors	Product innovation	Process innovation	Level of digitalization
Food and beverage	Medium-low	Medium-High	Low
Textile and clothing	Medium-High	Medium-High	Low
Wood	Medium-low	Medium-low	Low
Paper	Medium-High	Medium-High	Medium-low
Printing	Medium-High	Medium-low	Medium-low
Chemical	Medium-low	High	Medium-High
Pharmaceutical	Medium-High	High	High
Rubber and Plastic	Medium-High	High	Medium-low
Non-metallic minerals	Medium-low	Medium-High	Low
Metallurgy	Low	High	Medium-low
Metal products	Medium-low	Medium-High	Low
Electronic	High	High	High
Apparatus	High	High	Medium-low
Machinery	High	High	Medium-High
Motor vehicle	High	High	Medium-High
Other transport equipment	High	Medium-High	Medium-High
Other manufacturing industries	Medium-High	Medium-High	Medium-low
Repair	Medium-High	Medium-low	Medium-low
Construction	Low	Low	Low
Wholesale industry	Low	Low	Medium-High
Transport	Low	Low	Low
Storage industry	Low	Medium-low	Medium-low
Postal services	Medium-low	Low	Low
Publishing	Low	Medium-low	High
Programming and Trasmission	Low	Medium-High	Medium-High
Telecommunication	High	Medium-low	High
IT	High	Medium-low	High
Accounting and Consulting	Medium-low	Low	Medium-High
Architecture and Engineering	Medium-low	Low	High
R&D	High	Medium-low	High
Advertising	Low	Low	High
Other professional activities	Medium-low	Low	Medium-High

A sectorial segmentation versus innovation and digitalization appears from this table. Traditional industry sectors (including construction) have a lower propensity to innovate than the manufacturing sector, and have a low level of digitalization. Activities that belong to the advanced industry have higher propensity to innovate and a higher level of digitalization compared to other sectors. A strong propensity to innovate is recorded for services that require a high knowledge intensity. In other services, even though the level of digitalization is relevant, the propensity to innovate is lower.

In advanced industry sectors (machinery, motor vehicles, other transport equipment, electronics), and in services with high knowledge intensity (telecommunications, IT, R&D) the propensity to innovate is an important drive to ICT. While in the other sectors there is not an evident link between innovation and digitalization. So, this analysis underlines that the digitalization level is more correlated to product innovation than to process innovation. Nevertheless, this assumption cannot be taken as a general rule, since in more traditional sectors it is less relevant. Therefore, innovation is an important driving force for digitalization in specific sectors, that given their technological paradigms, exploit the ICT evolution to generate their innovation processes.

1.2.4 The Network Analysis

The success of innovation is strictly linked to the ability of its transmission in the economic system. In fact, the benefits of innovation are granted also to less innovative sectors that have a relationship with more innovative ones, increasing their propensity to innovate.

By analyzing the location of sectors within the transaction network, and characteristics of sub-networks, four different systems can be identified:

- Diffused transmission systems: innovator sectors, motor vehicles, R&D, rubber and plastic, machinery repairment. These sectors build large and dense subnetworks and the hierarchy of relationships is limited or absent. Since there is a strong connection among sectors, innovation can reach a greater number of them
- Selective transmission systems: electrical apparatus, machinery, IT and other professional activities. They are characterized by the presence of dense subnetworks which implies a strong connection among sectors, and accelerates the transmission of innovative processes
- Hierarchy transmission systems: electrical, other transportation equipment, telecommunication, textile and clothing. They are characterized by large but not dense subnetworks with hierarchical relations. This kind of system has two different effects on innovation: from one point of view the presence of an innovator intermediary sector accelerates innovation, but at the same time it is stopped by the minor density of subnetworks
- Weak transmission systems: paper, printing, chemical, pharmaceutical. They create small and not so dense subnetworks, with strong hierarchy relations. Here the

innovation spread is limited and slow, since only few sectors are involved and the connection among them is low

The direct relation between innovation and digitalization is more evident in diffused transmission systems and in hierarchy transmission systems since given their characteristics the transmission effect is very high. The phenomenon is slowed down in other systems, even though there remains a link between innovation and digitalization.

1.2.5 Use of ICT in Italian Firms

An efficient and innovative ICT sector allows the diffusion of digital technologies. The use of Information and communication technologies (ICT) has a big impact on the production system, but its performance is strictly related to the investments on complementary assets. Here the difference between SMEs and big ones is evident. Obviously, this gap is given mainly by different corporate needs, and since the company size is positively correlated with the operation complexity, it requires a higher speed of the internet connection. In addition to structural specifications, the limit of the diffusion of new technologies in SMEs is given by the relevant sunk costs that imply the adoption of these technologies.

In Italy among smaller firms only 18,4% are considered 4.0; for medium firms 4.0 the percentage is 35.5%; while for bigger firms 4.0 it is 47.1%.

1.2.6 Capital endowment

The propensity to digital transformation is affected also by the endowment of physical and human capital, since it affects the performance and the ability to capture and exploit the digitalization opportunity. Human capital is valued through its skills and know-how, taking into account both general and on-the-job training. While the physical capital is the monetary value of material and immaterial assets.

Firms with low level of digitalization and low intensity of capital are many and mainly belong to the construction and manufacturing sectors, while in market and commercial sectors it is more limited. On the contrary, firms with high level of physical and human capital and high digitalization propensity are scarce, and the difference among sectors is less relevant.

Therefore, for each level of digitalization, work productivity increases as the endowment of physical and human capital increases. At the same time, for each class of capital endowment, an upgrade of digitalization is associated with a higher level of work productivity.

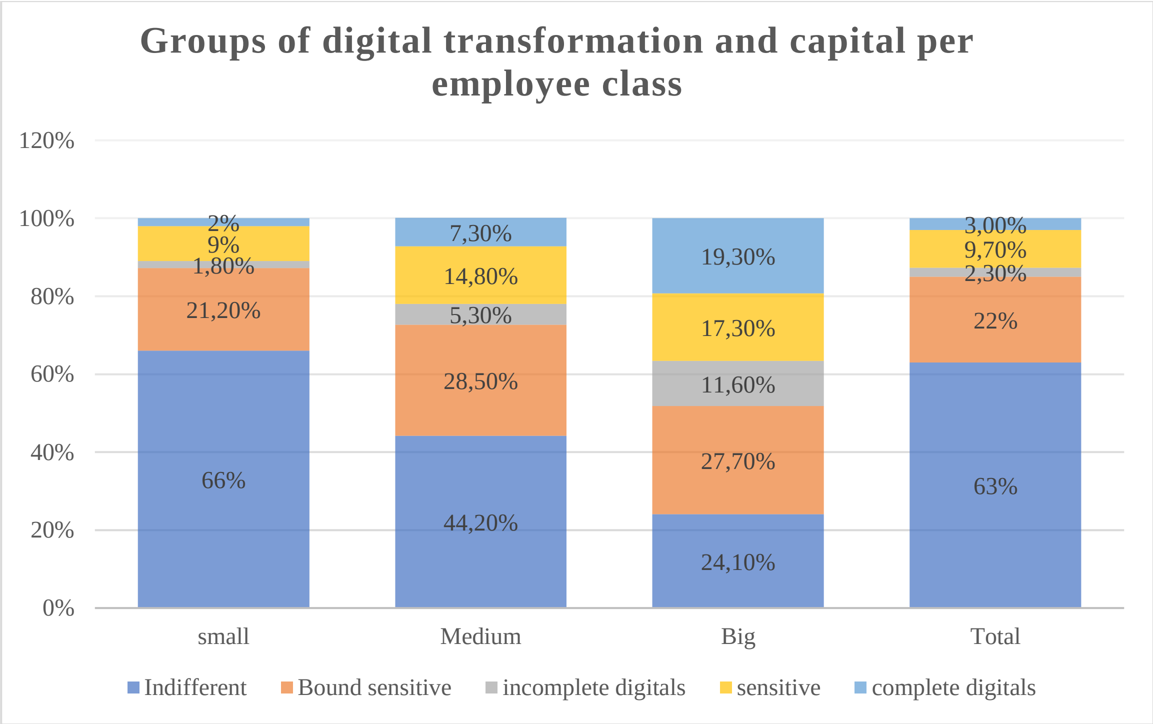
The Italian industry system is characterized by a broad presence of firms with low or medium level of digitalization, associated with a low level of physical and human capital.

1.2.7 Digital transformation profiles

The joint analysis of capital endowment and digitalization shows five digital transformation propensity profiles:

1. Indifferent: haven't made any kind of investments and do not consider them relevant, associated with a low level of capital endowment
2. Bound sensitive: consider relevant digitalization but the low-medium physical endowment and the low human capital endowment obstruct investments
3. Incomplete digitalization: a good level of digitalization has been reached but have medium productivity levels
4. Sensitive: with medium level of digitalization and medium-high capital endowment
5. Complete digitalization: high level of digitalization and high level of capital endowment.

	Digital transformation propensity groups				
Macro sectors	Indifferent	Bound sensitive	Incomplete digitalization	Sensitive	Complete digitalization
	Companies (%)				
Manufacturing	65,9	23,7	1,7	7,4	1,2
Construction	78,0	19,2	0,9	1,6	0,3
Commerce	56,5	25,4	3,8	10,7	3,6
Markets services	59,1	18,8	2,7	14,2	5,3
Total	63	22,0	2,3	9,7	3,0



To conclude, Italian firms' propensity to innovate is increasing, even though with different intensities and with different focuses. The network analysis shows that the Italian production system has higher innovation transmission propensity in product innovation than in process innovation. It is reflected also in the digitalization propensity; in fact, the degree of digitalization is correlated mainly with product innovation.

The following sectors show a strong innovation-digitalization link: electrical, motor vehicles, R&D, telecommunication, which belong to diffused or hierarchy transmission systems; and machinery, pharmaceutical and IT, which belong to selective or weak transmission systems.

When the implementation of ICT, the endowment of physical and human capital and the digitalization degree are taken into consideration, the gap between SMEs and big firms becomes relevant.

In the end, when these factors are combined, that is, the innovation activities, ICT implementation and capital endowment, the different profiles of the propensity to the digital transformation can be determined.

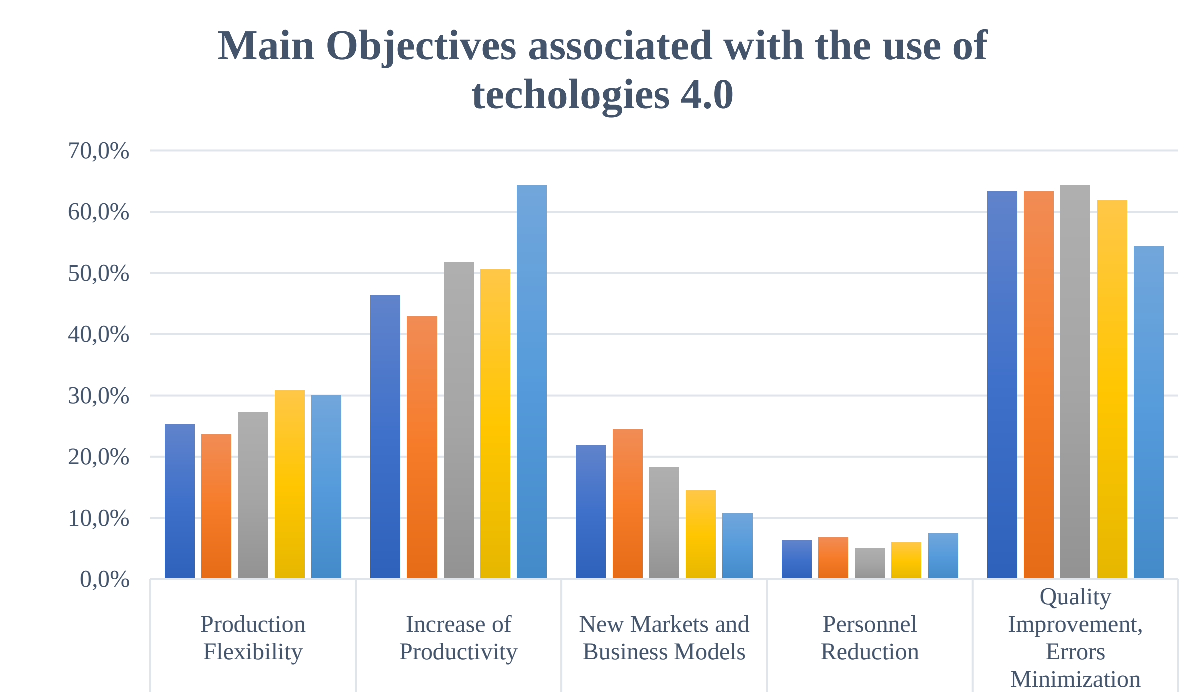
This analysis is fundamental in order to understand the Italian situation regarding the 4.0 industrial evolution.

In addition, from research done by “Universita degli studi di Brescia”,50% of Italian firms still haven’t started the path to become 4.0 industries. The government has a central role since starting from 2016[8] it has begun to create laws to motivate and support industries, to allow Italian firms to reach competitive levels in the market.

1.3 TAX EVOLUTION IN ITALY

Italian regulations have been revolutionized to increase the number of SMEs 4.0. Principal interventions are: hyper-amortization, R&D tax credit, Nuova Sabatini, tax credit for training 4.0, cybersecurity and vouchers for innovation managers.

The focus on different technologies depends on the goal of the firm. Of course, the main objective common to any company is to improve quality and minimize errors and costs, as well as increase productivity. In addition, bigger industries focus more on production flexibility while smaller ones choose to implement 4.0 technologies to enter a new business model.



	Production Flexibility	Increase of Productivity	New Markets and Business Models	Personnel Reduction	Quality Improvement, Errors Minimization
Total	25,3%	46,3%	21,9%	6,3%	63,4%
1-9	23,7%	43,0%	24,4%	6,9%	63,4%
10-49	27,2%	51,7%	18,3%	5,1%	64,3%
50-249	30,9%	50,6%	14,5%	6,0%	61,9%
>= 250	30,0%	64,3%	10,8%	7,5%	54,3%

Total 1-9 10-49 50-249 >= 250

[8] Legge di bilancio 2016

In the analysis of the spread of industry 4.0 in Italy, the difference between firms of different size emerges, as well as the technologies selection and in their application. It underlined that these differences are given by the different organizational structures that companies of different sizes have, thus creating different needs, different roles and skills. Moreover, different size firms have different budgets.

Bigger companies are already working to be competitive but also SMEs are trying to follow the transformation.

This result indicates that different laws and incentives based on the dimension and innovation attitude of the firms are needed to spread the 4.0 paradigm. In fact, government support can be considered a driving force of industry 4.0's spread since about 70% of firms stated that without the government support they wouldn't have made the investments in 4.0 field.

Firms will exploit the most suitable government support based on their needs: micro-enterprises, including start-ups, value more the financial support for the prototype development and consider crucial a partnership with firms that possess complementary technologies and know-how. The financial support is key also for small enterprises, while medium enterprises consider fundamental also staff training. Since bigger enterprises have a higher budget and along the years have already made many investments in technologies, they need a high level of competence and specialization to manage the application of new technologies in the operational processes.

To reduce the gaps in innovation capacity of different firms, the Italian Government in 2019 modified laws related to the industry 4.0 in favor of SMEs and reduced incentives for bigger ones. The reformulation was necessary since government found out that 99% of enterprise funds for 4.0 were given only to big companies, while SMEs were left behind from a plan that has the goal to encourage the innovation of technologies to all firms.

Main interventions in 4.0 field in the "Legge di Bilancio 2019[9]" are:

1. Hyper amortization
2. Tax credit for research and development
3. "Nuova Sabatini"
4. Tax credit for "training 4.0"

[9] Legge di bilancio 2019

5. Cybersecurity
6. Innovation manager 4.0

1) Hyper-amortization[10]: The amortization charges are increased up to 170% for some listed “smart equipment”, which is allowed to benefit from specific digital and technological transformation processes under the model promoted by the Italian Government plan “Industry 4.0”. whereas in the past year they were up to 150%[11].
   The purchase must be made by December 31, 2019[12], and this period can be extended up to December 31, 2020, on the condition that purchase orders have been accepted by the seller by December 31, 2019, and that at least 20% of their price has been paid by the same date.
   This year different rate ranges based on the amount of the investments have been introduced. As the amount increases the rate diminishes, with the objective of stimulating SMEs to digitalize.

Rate	Amount invested	
270%	For material goods up 2.500.00,00€	
200%	From 2.500.000,00€	To 10.000.000,00€
150%	From 10.000.000,00€	To 20.000.000,00€
0%	Over 20.000.000,00€	
140%	For immaterial goods	

The technical requisites are stated in the “Allegato A” for material goods and in the “Allegato B” for immaterial goods. Cloud-computing solutions are also facilitated within immaterial goods.

[10] Agenzie delle entrate, CIRCOLARE N.4/E del 30/03/2017 available at https://www.agenziaentrate.gov.it/wps/file/nsilib/nsi/normativa+e+prassi/circolari/archivio+circolari/circolari+2017/marzo+2017/circolare+n.4+del+30032017/CIRCOLARE+n.4_E+del+30-03-2017.pdf

[11] Legge di bilancio 2018

[12] Agenzia delle entrate, Super-amortization and Hyper-amortization available at https://www.agenziaentrate.gov.it/wps/content/Nsilib/NSE/Invest+in+Italy/Super-amortization+and+Hyper-amortization/?page=invest_italy

The benefit can be combined with:

- Nuova Sabatini
- Tax credit on R&D
- Patent box: an optional regime of facilitated taxation for incomes deriving from the use of intellectual property, industrial patents, trademarks, designs, and models, as well as processes, formulas and information relating to experiences acquired in the legally enforceable industrial, commercial or scientific field
- Incentives for company capitalization (ACE)
- Investment incentives for start-ups and innovative SMEs
- Central guarantee fund

Example of Investment of 250.00,00€: 30.000,00€ on "ordinary" machinery and 220.000,00€ on machinery with 4.0 requisites:

	Ordinary amortization	Hyper-amortization (170%)	Total
	30.000,00€	220.000,00€	250.000,00€
Deductible amount	30.000,00€	594.000,00€	624.000,00€
Tax savings (24% of deductible amount)	7.200,00€	142.560,00€	149.760,00€
Net investment cost (x- tax saving)	22.800,00€	77.440,00€	100.240,00€
Greater saving on net investment cost		40,8%	35,9%
% tax saving	24,0%	64,8%	59,9%

2) Tax credit for research and development are reduced from 50% to 25% up to a maximum amount of 2.500.00,00€ for each firm, with expenses of at least 50.000€ in R&D. The rate for expenses related to staff employed in R&D activities or contracts with universities, entities or organization for the development of R&D activities stays

at 50%, while for the next years it will be uniformed at 50%. The ceiling is reduced from 20.00.000€ to 10.000.000€.
It has broad cumulation, making the credit usable also with other incentives. With the exception of when other rules state an explicit prohibition.

3) The “Nuova Sabatini” allows firms to take advantage of the increased contribution, calculated on an annual interest rate of 3.575%, against investments in digital technologies and in waste tracking and weighing systems. Since its introduction the “Nuova Sabatini” has been an important tool to renovate the Italian productive system. This year it has been refunded with 48.000.000€ for 2019, 96.000.000€ for each year from 2020 to 2023 and with 48.000.000€ for 2024.

4) In 2018 the tax credit for 4.0 training was introduced, since the new digital era requires an update of the corporate skills, and the Italian plan for industry 4.0 is based on expertise, work and governance. It is also an important growth opportunity for workers. In 2019 the credit has been modified, differentiating its assignment based on the size of the firm. According to art. 8 of the “Decreto Attuativo”, the tax credit can be combined with other incentives as long as it stays within the maximum amount of aid available, provided by the regulation (UE) n.651/2014

Size of the firm	**Assigned credit percentage in 2018**	**Assigned credit percentage in 2019**
Small	40%	50%
Medium	40%	40%
Big	40%	30%

The ceiling has been differentiated following the same rule:

SMEs	300.000,00€
Big	200.000,00€

For this measure a fund of € 250,000,000 is foreseen for 2020.

5) The previous analysis underlined the crucial role of technologies in the evolution of industry 4.0, and the government, to support the investments in digital technologies, introduced a dedicated fund of 15.000.000€ from 2019 to 2021, in favor of the development of AI, blockchain, and IoT. And since the automation of the industry creates the need to upgrade cyber-security, a fund is created to strengthen cyber-security tools.

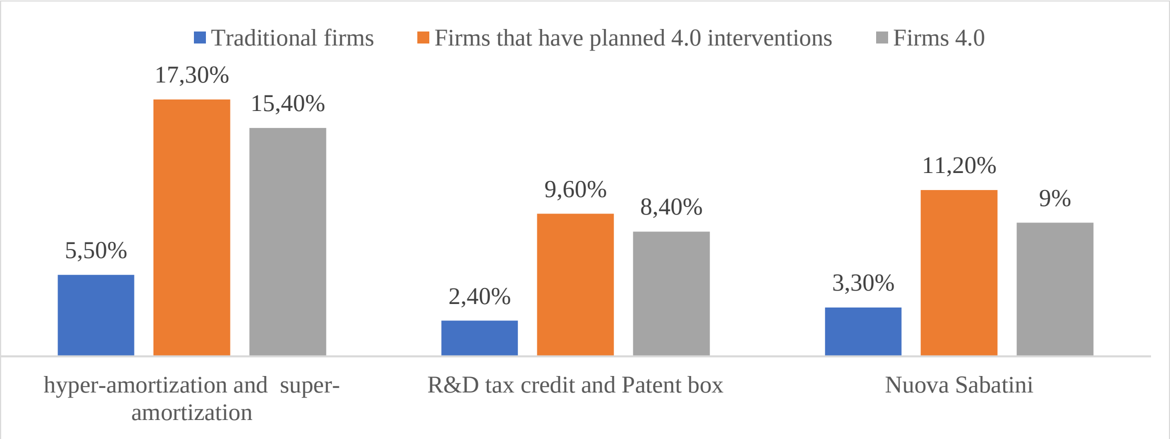
6) The voucher for the innovation manager 4.0. was introduced to support and stimulate the digitalization, mainly in those firms that still do not have the right and appropriate skills and knowledge. The provision is addressed to SMEs that hired managerial resources to reorganize themselves according to the technological transformation, and it is a non-fundable contribution. The role of the advisor is to identify the potential, the impacts, and the consequences of digitalization.

The voucher is addressed only to SMEs with these rules:

Size	**Total amount available**	**Contribution percentage**
Small	40.000€	50% of costs
Medium	25.000€	30% of costs
network contract	80.000€	50% of costs

The incentive is in the "de minimis" regime and can therefore be combined with other incentives different from State aid.

Firms that are taking advantage of government support are many. In fact, those who benefit from at least one incentive are: 22,7% of traditional industries, 47,8% of traditional industries with 4.0 investment planned and 56,3% of firms 4.0.



The most used incentives by firms are the hyper-amortization, R&D tax credit and patent box, and Nuova Sabatini.

The hyper-amortization had success in any kind of industries, even if based on their digitalization level exploited it in different intensity. This concession has been adopted by: 12,8% of traditional firms, 32,1% of traditional firms with 4.0 investments planned and 36,8% of firms 4.0.

R&D tax credit and patent box: 3,1% of traditional firms, 10,0% of traditional firms with 4.0 investments planned, and 17,0% of firms 4.0.

In fact, in the next chapter, it will be shown how the hyper-amortization and the R&D tax credit incentives are used in concrete industries.

2.CONCRETE & INDUSTRY 4.0

The application of industry 4.0 in the concrete sector allows the firm to introduce facilities which improve management control, account management, production control and the relationship between the client and raw-material suppliers.

Its implementation enables the firm to monitor, under all aspects, the production system. This simplifies reporting aspects by improving the decision-making process, and, consequently, improving the business as a whole.

2.1 CONCRETE PRODUCTION

In this section concrete production is illustrated, defining concrete, its functions and raw-materials. Based on different ingredients included in the mixture, different categories of concrete can be classified. In order to grant safety and good performance of the mixture, tests laboratories are needed. In the end production process and its phases, dosage and mixing, are described.

Concrete[13], that is the cementitious conglomerate, is a bound mixture intended for public work construction, such as roads, bridges, railways, sport facilities, dams, harbors, large and small houses, workplaces, industrial and agricultural warehouses, etc.

In each work listed the correct concrete mixture must be identified, based on the use of different components of single works as well as their environmental location.

From the economic point of view, taking as an example the construction of a building intended for residential purposes, the incidence of the concrete cost has been calculated to be only the 3%.

In contrast to the low-cost impact, the value of the concrete, in terms of quality and safety in its field application, is very relevant.

Before listing and defining technologies used to obtain a good concrete, an easy example is described to understand the problem complexity.

[13] Mario Collepardi, The new concrete, 2010

Anyone has made or has seen how a dessert is made. The ingredients are more or less always the same: flour, butter, oil, eggs, sugar, milk and salt.

No specific type of dessert has been defined, it could be a cake or a donut or a cookie. In each different type of dessert, the degree of sweetness, moistness, shape and color can change. The result depends on many variables, first of all: the proportion of the individual ingredients used is important; other parameters are cooking times, the shape of the cake, the type of oven (steam, ventilated, static, microwave). In addition, different tools can be used, such as hand or electric mixers, without forgetting that also different types of mixers are available. The result is influenced also by the work environment, in which temperature and humidity can vary.

There is still a detail that should never be overlooked. The aforementioned listed ingredients are the most common but the importance of their quality has not been mentioned. None of the ingredients listed have constant characteristics. This is an important concept in the concrete theme.

At this point a fundamental question arises: if we wanted to "industrialize" the process or at least guarantee results that are always very similar what should be done?

Going back to the problem of the concrete production, it will be illustrated that passages are assimilable to those described for the preparation of dessert.

Starting again from the ingredients' definition, the fundamental element for concrete is the cement.

According to the European regulation EN 197-11, cement is a hydraulic binder, that is a finely ground inorganic material which, when mixed with water, undergoes a reaction and hydration process which transforms the materials into a paste that hardens and which, once hardened, maintains its resistance and stability even under water.

Different types of cement are available on the market, each marked with the abbreviation CEM, followed by a roman number which indicates the composition and a number that can be "325", "425" or "525", which indicates its resistance in kg/cm2, measured after 28 days from when the cement is poured.

Five different categories exist, each more or less suitable for the intended use:

CEM I = Portland Cement: suitable for the prefabrication of simple and prestressed reinforced concrete;

CEM II =Portland Cement of mixture, similar to the CEM I, but given its different chemical components it is suitable for the most common uses in the production of normal and prestressed reinforced concrete and also of prefabricated elements;

CEM III = Blast furnace Cement: particularly indicated in situations where concrete is subject to chemically aggressive environments and for the construction of large-scale works

CEM IV = Pozzolanic Cement: has a high resistance to chemical attack;

CEM V = Composite Cement: suitable for making concrete exposed to moderately aggressive environments, such as sea water, acid water and sulphate soils.

In some cases, in particular for the last two categories, the exposure class is required, in which the purchaser of the work specifies the environment in which the concrete will be used, and the type of work to be carried out, such as, foundation piles, beams, roofs, flooring, etc.

In addition, taking into account the 3 different subtypes of cement, which varies based of the percentage of the ingredients (for instance the clinker, the most diffused one), and initial resistance parameters, 150 different cements can be classified.

The aggregates are the second element present in any concrete. When aggregates are taken into consideration the question becomes really complex. To simplify, aggregates include: sand, gravel, expanded clay, vermiculite and perlite.

Origin, form and quality are the elements that characterize different natural aggregates used for making concrete: alluvial gravels and sands extracted from river beds or quarries; crushed stone or sand from rock crushing. The natural aggregates' form depends on their origin: those of fluvial origin are more or less rounded and smooth; those shattered have sharp and irregular edges.

The aggregates' quality depends mainly on its petrographic nature, thus from the mineralogic composition and from physical and chemical properties that derive from it.

In any concrete mixture, in general, anywhere from one up to three different aggregates are present.

Qualitative elements of aggregates are many. To evaluate them different methods and laboratory analysis are used. The results indicate the usability, and whether they are excluded from some or all mixture applications. For instance, for each aggregate the elements evaluated are the size (granulometry), bulk mass (specific weight), impurity presence, water absorption capacity, presence of organic material or other elements that could react to acid or water itself, etc.

Among sands, the preferred are the siliceous and calcareous ones.

In any concrete mixture usually one or more additives are used. Their function is linked to environmental factors (hot, cold), distance from the production site and destination (retardants) and the work type (accelerators, whinners, anti-withdrawal). They can be liquid or in powder state.

Additives also include different types of fibers used to obtain specific types of performance. Fibers can be of different materials, such as plastic and steel, and have different forms and dimensions.

Additives can be used also in transport and pumping phases, following the loading one.

Water is also a fundamental element, since without it the chemical reaction that determines concrete characteristics does not happen.

With these premises, it is possible to better define the complexity of the problem.

In order to grant to reinforced concrete structures performances required by the designer, such as the degree of durability, workability and mechanical strength, a study on the concrete mixture must be done: the MIX design. It must take into account, as already mentioned, characteristics of available raw-materials.

When the mixture is designed, the correlations taken into consideration are:

The workability increases as the quantity of water used in the mixture increases, and it depends on the characteristics of the aggregates used (expected maximum diameter and aggregate surface: smooth or rough) and on the presence of specific additives.

The mechanical strength is a function of the water/cement relationship and of the quantity of cement used, as the first decreases and the second increases the mechanical strength increases (if measured after 28 days it also depends on the binder type and class).

The degree of durability grows in inverse proportion to the water/cement relationship.

Therefore, the water/cement relationship is the principal parameter of the mixture design, which must be suitable to grant performances required by the concrete. It means that in order to increase the workability, without additives, the quantity of water must be increased as well as the cement content to keep constate the water/cement value needed to not compromise the degree of durability and mechanical strength.

The right concrete mixture design is a necessary, but not sufficient, condition to grant the concrete quality required by the designer. In fact, the concrete quality depends also on the executive process, including the transport phase. The fresh conglomerate must be adequately thrown and constipated, matured immediately after the possible dismantling of the forms in wood or steel, for an adequate number of days (at least 3 protecting it from the excessive evaporation).

Once the MIX design is planned it is realized in the productive process, dividable into two phases: dosage and mixing.

The dosage phase is the most complex one, in which all the plant components come into play:

- Storage hoppers
- Cement silos
- Cement level meters
- Additive dispensers
- Probes for measuring the humidity of aggregates
- Extraction vents
- Conveyor belts
- Load cells

- Cement scale
- The cement extraction augers
- The inclined conveyor belt for loading the concrete mixer
- The continuous or discontinuous mixer
- Security systems
    - Detection of mechanism blocks
    - Intrusions in the areas of moving components

The presence of each single component depends on the types of plant:

DRY: for the dry loading of the concrete truck mixer, with single or double loading point

WET: for the concrete truck-mixer loading equipped with planetary or double-axle mixer for concrete pre-mixing, the plant can have a single or double loading point

Each component listed can be controlled from the operator console.

In the past few years, technologies have allowed the plant to make dosages of the mixture components through automation systems (which will be described later), which make the productive process simpler.

Giving commands to electromechanical components is not sufficient to reach elevated quality standards, also due to the characteristics of the material used. In fact, great deviation and measurements that exceed the tolerances required by current regulations often occur between expected results and the final product.

For example, it is common that, given the same opening time of an inert extraction port, the weight is significantly different from the one measured at the beginning, which is caused by the process drifts that can more or less affect the result.

Each production slot is called a productive CYCLE, and it can vary from 1 to 10 mc of concrete.

Referring to the process drifts, it can be said that the single CYCLE didn't occur correctly.

Before describing the solutions to the problem exposed, the second phase of the process, the MIXING one, is described.

In the case of a DRY plant, mixing is delegated to an external component, that is the concrete truck mixer, a means of transport specifically designed for the logistics of cement conglomerates. The concrete mixer is composed by a truck, where a container, called "glass or drum", is installed. In some models it can even contains 11 mc of concrete and it is kept in rotation until the concrete is unloaded. Inside the glass, shovels are installed, in order to increase the mixing capacity.

In the WET plant the mixing phase is carried out directly at the plant. There are two types of mixers: continuous or discontinuous. The continuous one has a shape of parallelepiped with a rectangular base, and is powered by the dosage facility and mixes and pushes the mixture towards the exit through two helical mixers. The discontinuous mixer is cylindrical and equipped with planetary mixers, once it is filled with the pre-dosed mixture produces a predetermined quantity of concrete.

In both cases the mixture is then unloaded in the cement mixer to be transported to its destination.

The preparation of low-binder mixture (cements), or mixture with bituminous emulsions in the case of aggregates coming from milling of road asphalt, is equally possible with plants equipped with mixers. These mixtures, called "mixed cements", are transported with by truck and are used for non-structural works or for the realization of road foundation (in the case of bituminous based mixture).

2.2 FEATURES REQUIRED

Before illustrating the automation of a concrete plant, the minimum requisites for the compliance with industry 4.0 following the Piano Nazionale, of the Legge di bilancio 2016 and successive integrations and modification, are reported. These minimum features needed to consider a plant compatible with 4.0 requisites are listed in the Allegato A of the hyper-amortization regulation. To access the benefit, based on the characteristics of the good, a certification or self-certification is required. Some examples of applications of the 4.0 requirements are then described: automatic or semiautomatic conduction, revamping activities, and use of sensors (silos).

2.2.1 Minimum features required

The previous analysis showed that hyper-amortization is the incentive most used by the majority of firms. It is addressed to all subjects with a business income, including individual enterprises subject to IRES, that have a legal tax office in Italy. The benefit is also granted to permanent organizations residing abroad, independently from the legal form, the company size and the economic sector in which it operates.

How to access the benefit:

- The right to the tax benefit accrues when the order has been accepted by the seller by the 31 December 2019 and payment of at least 20% has been made by the same date, and the good delivery occurs by 31 December 2020. So, the law allows the firm to take advantage of the benefit provided also during the following year, if the conditions are fulfilled, since over the years the law could change
- Hyper-amortization investments higher than 500.000€ for each good, require a conformity certificate issued by an accredited certification body, or a sworn technical appraisal by an expert or engineer, registered in the respective professional registers. They must certify that the asset possesses technical characteristics such as to include it in the lists referred to in annex A (Allegato A), for material goods, or in annex B (Allegato B), for immaterial goods, of the "Legge di Bilancio".In addition it must be proven that the assets are interconnected with the management production corporate system or the supply chain
- For investments on assets lower or equal to 500.000€ it is possible to access the benefit automatically during the balance sheet writing phase through self-certification; obviously it can be replaced by the sworn technical appraisal or by a conformity certificate.

In addition, the acknowledgement of the hyper-amortization benefit is important since the Allegato A (article 1, paragraph 9) lists the minimum features an implant needs in order to be considered 4.0. Obviously, machinery with equal or higher technological features is subject to hyper-amortization.

The Allegato A specifies that functional goods for the technical and digital transformation companies, according to the Industry 4.0, are capital goods whose operation is controlled by computerized systems or managed by appropriate sensors and drives such as machine tools and systems for the production of products through the transformation of materials and raw materials.

All types of machinery must have these characteristics:

- Control through CNC (computer numerical control) and/or PLC (programmable logic controller)
- Interconnection to firm's IT systems, with remote loading of instruction and/or part program
- Automated integration with the firm's logistics system or with the supply network and/or other machines of the productive cycle
- The simple and intuitive interface between man and machinery
- Compliance with the most recent parameters of safety, health and hygiene at work.

Moreover, to make machinery comparable or integrable with cyber-physical systems, they must meet at least two of these characteristics:

- Remote maintenance and/or remote diagnosis and/or remote-control systems
- Continuous monitoring of working conditions and process parameters through appropriate sets of sensors and adaptability to process drifts
- Characteristics of integration between physical machinery and/or implantation with the modelling and/or simulation of one's behavior in the process (cyber-physical system).

Nevertheless, for some certain capital goods the mandatory features of Interconnection to firm's IT systems, with remote loading of instruction and/or part program, is not necessary. This is referred to some machine tools, such as, cutters, circular saws, drills, crushers and grinding mills, which, since they are projected for a single work cycle or for a single completely standardized process, do not need to receive operative instruction, neither in relation to the sequence of action or activities to be performed nor in relation to processes parameters or variables.

Therefore, the condition that the asset, by a way of example, is capable of transmitting outgoing and functional data to meet the additional requirements of remote maintenance and / or remote diagnosis and / or remote control and continuous monitoring of working conditions and process parameters, is sufficient to access the hyper-amortization benefit.

These requisites make clear that a machinery by itself cannot be defined 4.0. A machinery is prepared to be implemented in a digitalized system if has certain characteristics to fulfill all the constraints.

2.2.2 Certification and Self-certification

Subjects authorized to release conformity certificates are bodies for the Certification Management systems (regulation UNI CEI EN ISO/IEC 17021) and bodies for the Product Certification (regulation UNI CEI EN ISO/IEC 17065).

The examination is structured into two different and subsequent phases. The first is a preliminary step that verifies technical requisites of the good, and can be conducted even before the purchase. The second one is conclusive, and verifies the interconnection. For this reason the inspection must be done when the good is installed and fully operative and obviously interconnected.

In the first phase a first part of the technical report is released. The good is intended as a "prototype", where its operating conditions or tests at the manufacturers' laboratories are examined. Here it is declared whether the asset falls within categories subject to tax benefit, and if they have requirements for the prototype configuration in the manufacturer's laboratory or factory. In some cases, interconnection and integration requisites cannot be verified in this phase at the supplier, thus they must be inspected in the second step.

The second phase, in fact, verifies the proper operation and the interconnection on site. A declaration is release stating if the assets falls within categories of assets subject to tax benefit, listed in the Allegato A or B. And if they have additional requirements needed for the configuration at the user's factory.

The steps for the conformity certificate release are:

1. Collection of preliminary information related to the good
2. Verification of the feasibility of issuing the certificate
3. Detailed description of the product analysis
4. Technical report inspection and preparation
5. Certification release

The information collected in the first step are the following:

- Personal data of the applicant firm

- Number of total employees and number of people involved in the reference activity of the asset
- Chamber of commerce view, with the NACE and ATECO codes of the activity for which the asset is used
- Category to which the asset belongs
- Asset's characteristics definition
- Unique identification of the asset (manufacturer, model, serial number, ...)
- Technical data of the asset (data sheet, technical description, brochure, manual, blueprint, ...)
- Context in which the asset is inserted - plant technical data, factory layout, layout of the asset control system, network diagram and interconnection
- Good's value.

In the second step an offer is formulated for the activity if the good falls within eligible assets.

In the description of the product of the third step the following is reported:

- Technical description of the good (manufacturer's specifications, integration into the company's production system, ...)
- Economic - administrative documentation of the asset (offer, order, delivery note,)
- Technical description of interconnection requirements (information exchange methods, unique IT identification)
- Representation of flows of materials and / or raw materials and semi-finished products and information
- Description of the methods capable of demonstrating the interconnection of the asset (testing, validation, ... reports relating to the implementation and interconnection of the asset)

In the fourth step the documentation in analyzed and the asset is inspected at the user's location to verify the consistency of the information, in order to prepare the Technical Report.

In the final step, if the asset respects all the characteristics for the tax benefit the conformity certificate is released.

2.2.3 Automatic or semiautomatic conduction

Among the means of work of the plant, mechanical shovels necessary to power storage hoppers are included and have to respect the automatic or semiautomatic conduction requirement.

According to the MISE's circular, devices used for loading and unloading, handling and automatic weighing of pieces, which belong to the category of operating and driving machines, can be subsidized. However, they must be automatic or semiautomatic guided vehicles, in addition to meeting other constraints of the Allegato A.

In fact, the circular specifies that it is a technical characteristic through which mobile machines meet interconnection and automized integration requirements.

However, the MISE recently specified that, with regards to the semiautomatic or assisted driving for operated machines, systems that require the presence on board of an operator for security reasons and for other operations are also included.

Since the circular requires automatic or semiautomatic driving for mobile machineries, operative machineries different from mobile, such as cranes and bridge cranes, do not need to fulfill this requirement.

2.2.4 Revamping activity

The firm can benefit from the hyper-amortization also for revamping activities, in which the machinery will produce something different, and modernization activities, where there is not a substantial modification of the machinery. It Is valid as long as the purchase and implementation of devices, instrumentation, and components necessary, respect the 5+2 condition of the Allegato A. It is true also for assets subject to revamping.

The revamping activity, in the 4.0 environment, consists in making changes to improve some productive aspects of dialogue with the present company systems through the interconnection with the production process.

Only the portion of new assets that will help to allow the machine or plant to be subject to revamping or modernization will be subject to hyper-amortization. This means that systems and components already owned by the company are not included in the tax benefit calculation. In addition, the new component's value must exceed the residual value of the original asset.

In the event that the good subject to revamping is dated, that is without "CE" trademark deriving from the application of the machinery directive, substantial modifications are needed so that the CE marking and all that it entails is applied, in order to satisfy compliance with the most recent parameters of safety, health and hygiene at work requisite.

When the firm wants to purchase quality assurance and sustainability systems, in order to interconnect them with existing machineries, it is not subject to revamping since no machinery ability is modified.

Industrial revamping is a quick and simple way to transform the firm into industry 4.0. It is mainly recommended to SMEs in order to quantify the investments in proportion to their turnover. Thus, with a revamping activity that follows requirements of Piano Nazionale Industria 4.0, the firm has the same tax advantages, thus spending less, since it is not necessary to buy a new machinery.

In fact, sometimes the transformation to 4.0 can happen even with only the IoT implementation.

One of the best practices of modernization or revamping, for the purposes of compliance with industry 4.0 criteria, is the use of apparatus for converting analog signals to digital signals. In order to re-use as much as possible existing industrial devices by connecting them to the factory system via IP protocol.

For instance, a load cell used in an inert conveyor belt or in a truck weighbridge constitutes a medium value apparatus. But in the event in which it is fully functional and it is certified that is connected via analogue system, re-use it in a production plant is appropriate. Thus, it is possible through modernization or revamping activities finalized to its digital transformation (industry 4.0) using devices (eg MOXA ...) which allow its interconnection by IP Protocol (from RS232 port to RJ45 port).

2.2.5 Use of sensors (silos 4.0)

One feature that characterizes industry 4.0, as already mentioned, is the use of sensors. For firms that operate in the concrete industry a way to exploit the hyper-amortization benefit Is to modernize any components.

For instance, the firm can equip storage silos and aggregates storage hoppers with sensors, which would give the asset not only the simple function of storage, but also the active hygrometric control of the raw materials or stored products.

The circular states that the asset itself is excluded from the benefit, but the addition of sensors, ventilation systems or other devices and plant components functional to the specific productive process, would provide an autonomous requirement for the hyper-amortization. In particular, they can be classified among the process monitoring systems that allows the following: ensure and track the quality of the product or of the production process; qualify the production processes in a documentable way and connection to the factory information system. It is still necessary to verify the interconnection to the factory system.

Another example of sensors application is for safety operators on board plant. The aim is to grant higher safety to operators, in fact, all the mobile parts of an implant are equipped with sensors. Cables with emergences objectives, with tear-off limit switch manual. It happens thanks to a signal sent to the PLC.

2.3 R&D

The building, modernization and revamping of a plant requires the feasibility study. This examination is compatible with the R&D tax credit logic. For this reason, the calculation of the R&D expenses to access the benefit is described.

The design of a plant for the production of cement conglomerates often requires a feasibility study based on the materials available in the area surrounding the plant itself, including materials from C&DW (construction and demolition) as well as based on the needs of mixtures dedicated to the uses requested by the territories. Those feasibility studies include analysis and researches compatible with the with R&D logic, including in these activities also prototypal phases.

Therefore, the costs incurred in consulting and activities for the preparation of the proto-types are fully included in the R&D logic.

The tax credit for R&D is the second most used incentive. It has already been clarified that the tax credit for 2019 has been reduced up to 25% for certain R&D activities. Any firm which performs activities related to Research and Development can benefit from the tax credit.

Three different types of R&D activities can be identified: basic research, industrial research and experimental development.

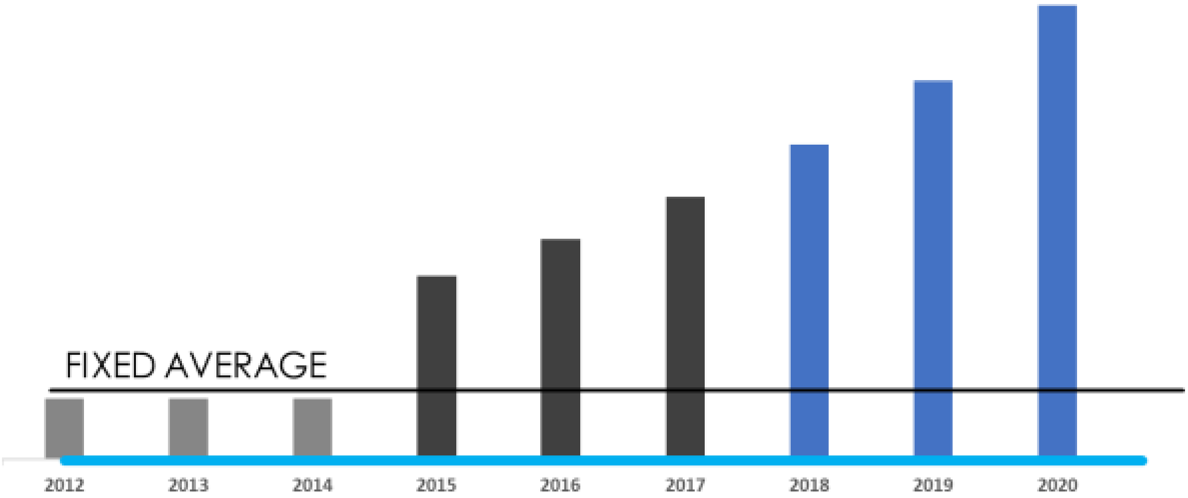
The basic research it is the set of studies, experiments, investigations and researches that do not have a finality defined with precision, but which are to be considered of generic utility for the enterprise.

The industrial research is finalized at a specific product or production process. It consists of a series of studies, experiments, investigations and researches that directly refer to the possibility and utility of carrying out a specific project.

The experimental development is the application of research results or other knowledge possessed or acquired in a project or program for the production of new or substantially improved materials, tools, products, designs, systems or services, before the start of commercial production or of the utilization (also called pre-competitive development).

The benefit is calculated on the incremental value of R&D expenses recorded in each of the 2015-2020 tax periods for which it is intended to benefit from the subsidy compared to the annual average of the same expenses in the three-year period 2012-2014.

That is, the firm can benefit from the tax credit also from the previous three years, unless R&D actions have not been indicated in the financial statement.

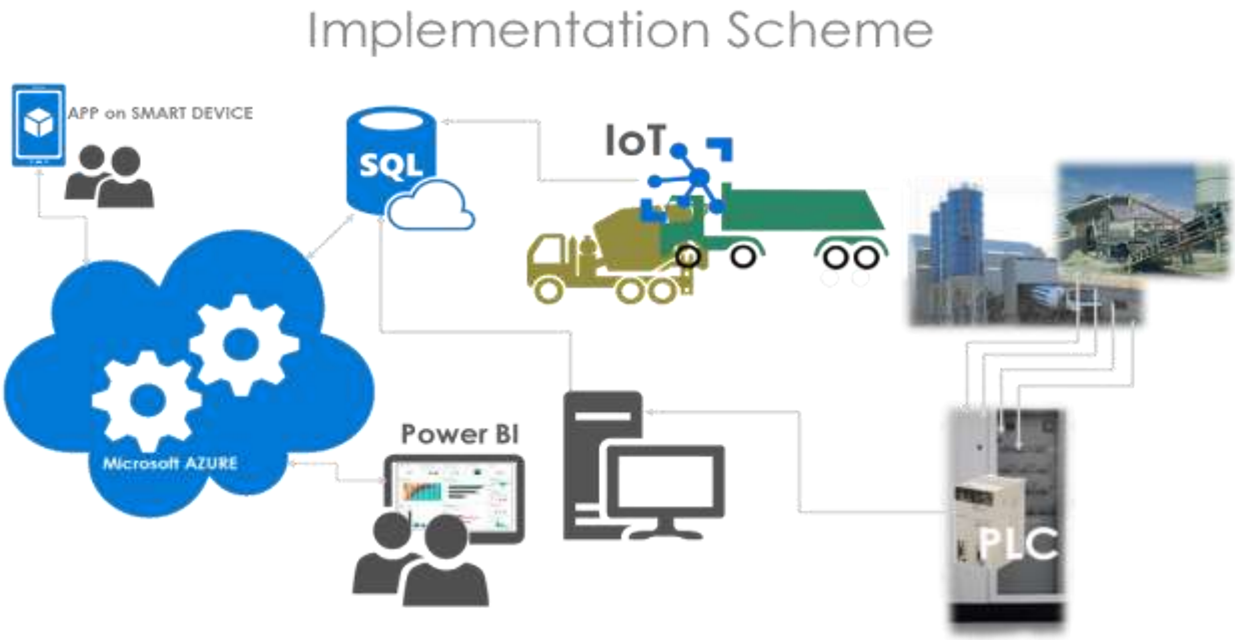


2.4 IMPLEMENTATION SCHEME AND TECHNOLOGIES

CONCRETE 4.0 ® created a project for the automation of the concrete plant.
Technologies applicable in this field are: PLC, IoT, SQL, POWER BI, app, data warehouse and IP. Below the implementation scheme and technologies enabling digitalization are described.

The graph that follows represents the production flow of cementitious conglomerates.

It represents in particular the application of components that form a project called CONCRETE 4.0 ® (CONCRETE 4.0 is a registered trademark of the company CONSELAB Ltd). The graph defines the implementation scheme of technologies applicable to the world of cement conglomerate production to achieve compatibility with the requirements of industry 4.0.



Before describing how the system works, and how these technologies are applied in the concrete field, the general definition and advantages of technologies are reported.

2.4.1 Technologies

PLC

PLC (Programmable Logic Control) is the device[14] most widespread in industrial automation. It is projected to be able to operate even in hostile electrical conditions: 24/7 in critical conditions of temperature, humidity and voltage surges.

Since it is a full-fledged processor, the PLC is made-up of a hardware part formed by cables and other physical objects and by a software part, which consists in the instructions forming the program to be executed.

It acquires the input signals that reaches it from the field sensors and, based on their value and on what is established by the program, it emits the necessary output signals directing them to the actuators.

[14] PLC, available at http://www.edutecnica.it/sistemi/plc/plc.htm

The PLC is a central processor for any real-time decision of the production process. It is projected as an autonomous device that reacts to local inputs and outputs.

Internet of Things (IoT)

Internet of Things (IoT)[15] includes many technologies which allow any type of apparatus to be connected to the internet.

It is aimed at monitoring, controlling and transferring information, in order to carry out consequent actions.

The internet evolution allows the extension of internet to objects and real places. It enables the interaction with the network and they can transfer data and information. Things interact with the surrounding world, thanks to their "intelligence", so they find and transfer information between the internet network and the real world.

Therefore, an electronic identity is assigned to anything that forms the world, through the RFID (Radio-Frequency IDentification) and other technologies such as the QR code.

[15] Mauro Bellini, IoT (Internet of Things): significato, esempi e applicazioni pratiche, 9 Feb 2019, available at https://www.internet4things.it/iot-library/internet-of-things-gli-ambiti-applicativi-in-italia/

The IoT associates internet with real objects of everyday life; consequently, objects and devices are always more connected creating a dense network of places that need control, automation and survey.

It increases visibility and agility, building competitive advantages. In addition, it creates new business opportunities and redefines the relationship with clients.

When clients and infrastructure are connected, new opportunities can be unlocked, efficiency increases, customers are more satisfied and so the firm gains a real advantage over the competition.
It opens to new business opportunities: organizations can more easily identify trends, be aware and prepare for new opportunities, predict customer and partner behavior and innovate faster through the exploitation and analysis of data,

It redefines customer service: with the Internet of Things, a greater insight into customers' wants and needs is gained, allowing the firm to provide what they want—sometimes before they know they want it.

A truly personalized experience that exceeds customers' needs allows immediate access to inventory information via connected devices, or offers a quick and simplified service. And that leads to loyal, repeat customers.

It's important to see IoT as not just a standalone strategy or a set of services that work independently. IoT is part of a complete, comprehensive device and cloud strategy that entails every aspect of digital business strategy.

SQL

SQL (Structured Query Language[16]) is a (de facto) standard language for relational DBMS (database management system). It is a declarative language (non-procedurals), that is, it does not specify the sequence of operations to accomplish.

[16] Introduzione a SQL available athttps://www.html.it/pag/55229/introduzione-20/

POWER BI

POWER BI[17] is an analysis business service. It offers detailed information to favor rapid and informed decisions.

Power BI is a collection of software services, apps and connectors that interact to transform unrelated data sources into coherent, visually appealing and interactive information.

In fact, it transforms data in visible objects and allows the firm to share them with other colleagues in any device. Moreover, it explores and analyzes data, both locally and in the cloud, in a single view. Therefore, it is simple and able to obtain information from data that could be on an Excel spreadsheet or collection of cloud data warehouse, or from a local database.

Thanks to this service, it is possible to share personalized dashboard and interactive reports, and gives the opportunity to renovate governance and safety functionalities of the organization.

It is important in the process since real-time in-depth and specific analysis helps to improve the product's quality, and the development and time-to-market time is reduced.

In the third chapter an application case of the data analysis through the Power BI is described; some significant examples of reports and related explanations are included as well.

MICROSOFT AZURE

MICROSOFT AZURE[18] is a set of cloud services in continuous expansion, that helps organizations to handle professional challenges. It allows them to create and distribute applications on a global network, using the preferred tools and framework. It also allows the firm to manage big data quantities, exploiting the cloud and a system that, thanks to platform scalability, can be adaptable to any needs.

Azure is a learning machine. The idea is to train the computer to interpret data and respond to certain situations, and its algorithms can be integrated with existing applications.

The learning machine allows the firm to extrapolate big amounts of information from data unknown by the developer or by the professional and it makes an automatic classification of

[17]Power BI available at https://powerbi.microsoft.com/it-it/

[18]Cos'è Azure? Available at: https://azure.microsoft.com/it-it/overview/what-is-azure/

data. It identifies hidden correlations among objects and concepts and offers indications for future trends based on what happened in the past.

APP

The information obtained with analysis tools as well as any alarms generated by system, including the Business analysis report, can be consulted though a special “app” that must be seen through any type of device.

DATA WAREHOUSE

It is a centralized repository of information, which can be analyzed to take more conscious decisions. Data flows into the data warehouse from transitional systems, relational database and others, usually at regular intervals. It is possible to access to data through Business Intelligence (BI) tools, client SQL and other analysis applications. Data and their analysis are critical factors to guarantee competitiveness to the firm. Report, control panels and analysis tools are essential for extracting in-depth information from data, monitoring business performance and support for decision making.

Internet Protocol IP

Internet protocol IP is the principal internet protocol, thus is vital for the exchange of computer networks. It must guarantee the correct sending of the package from the sender to the recipient. The IP establishes a format that defines the type of description of these packages (also called datagrams).

2.4.2 Implementation Scheme

Through the connection of the components of the production plant listed above to the controls of the electrical panel equipped with PLC components, which are in turn interconnected by means of an IP network to a PC station equipped with an application specifically designed and built for this specific type of production, the exchange of data is possible in both directions: to the PLC to communicate the production parameters and from the PLC to receive return data from the sensors (included alarms produced by security systems).

The presence of the IoT is also reported in the scheme. The IoT apparatuses are installed on the means of transport. The apparatuses are able to transmit relevant information detected by sensors installed on vehicles, such as the effort of the rotating drum with possible additions of additives or water carried out by means of suitable dispensers, consumptions, travel times, journeys, etc.

2.4.3 Data

The information exchanged with the described apparatuses are collected on appropriate databases, some local as the scheme represents, are memorized or replicated on SQL database Azure Server. Thanks to the use of standard tools of Business Intelligence, as the Microsoft Power BI, the database allows the monitoring of the document information related to production, using any type of device connected to Internet.

Why is it important to apply these technologies to the production of cementitious conglomerates?

Regulation on construction, updated February of last year and known as NCT 2018[19], reaffirms the responsibility of the construction manager, in particular regarding the use of concrete.

In addition, since march 2019 the regulation establishes that it is the job of the construction manager to prepare the concrete samples to be sent to the official laboratories that will produce the certifications valid for the purposes of civil engineering practices.

The samples are made by taking small portions of concrete from the one which is about to be implemented, filling cubic shapes generally with side equal to 150 mm.

For each withdrawal generally 4 to 6 specimens are prepared.

The construction manager is also responsible for their correct storage and delivery. Together with a sampling report, at the official laboratory, the construction manager can delegate to other subjects the operations described: withdrawal, storage and delivery.

Each single concrete cube is subjected to resistance tests, but before their measure and weight are verified. In general tests are done seven days after the sample production and are repeated after 3 weeks (28 days total) in order to verify the resistance. The regulation fixes a maximum deadline for carrying out the test 40 days from the withdrawal otherwise the test must be carried out on the work itself by coring and exclusively by technicians sent by an official laboratory.

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[19]Gazzetta ufficiale della Repubblica Italiana, Aggiornamento delle «Norme tecniche per le costruzioni».,20 Feb 2018, available athttps://www.gazzettaufficiale.it/eli/gu/2018/02/20/42/so/8/sg/pdf

It is easy to understand that the system used to demonstrate the concrete quality is fundamental in order to grant safety to buildings and any concrete works.

It is equally clear that the tests carried out in this way give a result that is strongly deferred over time with respect to the time of production. In the case in which the resistance results differ significantly from the expected performance, relevant economic consequences can occur, mostly because test results can arrive when the work has already reached most advanced stages of production.

Damages caused by the installation of inadequate concrete are extremely disproportionate if compared to the value of the concrete itself. These events are usually the origin of delays of delivery of works and consequently penalties with disputes involving production companies will be applied.
The adoption of technologies, mostly if in line with industry 4.0 requisites, becomes absolutely decisive to guarantee very high-quality materials.

2.5 CONCRETE 4.0

The automation of a plant, as already mentioned, regards all the firm's processes. The implementation of the enabling technologies changes the production of concrete, control systems of the plant, raw-material supply, MIX design and predictive reporting. Moreover, the digitalization modifies and expands the main technological specifications, and creates new advantages for the firm.

2.5.1 Automation of the Production Plant

In Italy the majority of production plants are equipped with an automation system, even if in many cases the implementations are dated, that is the implementations are made on obsoletes platforms.

Nevertheless, parts of requisites required for the compliance with industry 4.0 are implicitly respected, included for example requirements regarding process drifts, security and interfaces. Rarely these systems are integrated with the management system of the factory, and in the case in which they are integrated not always the connection occurs on IP protocol.

Therefore, revamping and modernization activities can be applied for the sector of concrete production, in order to benefit from tax benefits provided for industry 4.0. In the third chapter is described an application of this case.

The task of the software for this type of production plant is now described.

The software automatically manages the entire productive cycle of the plant that produces concrete or similar materials. Thanks to a modern development platform and its DATABASE, it provides unmatched potentials in the sector.

The platform must be safe and well structured, and, through its appropriate configurations, it must satisfy the plant's needs for the cementitious conglomerates' production. In addition, given the database's power and versatility, it is possible to manage its functions in a simple and fluid way.

The easy-to-use and complete software, with its specific terminology, has the objective to satisfy the real needs of the yard and yard operator, respecting the qualitative standards given by the most important tender specification.

The graphic interface performs scrupulous checks for the various functions and for the safety for the employed personnel, allowing excellent plant management both from local and remote positions.

The maximum system configurability of the plant provided is:

Dosage

- Max 10 different aggregates
- 6 concretes
- 7 additives
- 2 types of water (clean and dirty) with flow meter/scale

Unloading:

- 1 loading point for concrete mixer

In addition, the software allows a complete mastery of the concrete mixing plant as well as in the case in which more production points are planned.

All the production processes' steps must be automized, reducing the need for constant monitoring of each individual phase to a minimum.

The software is projected to be a multi-user one, to offer the possibility of receiving real-time assistance with low maintenance costs and with extremely short solution times. It includes a billing system, which is equipped with archives and necessary correlated function for correct management, for Transport Documents emission compliant with UNI standards and with tenders' specifications. Documents must be personalized to perform graphic printing on white paper. Moreover, the software can be integrated with the company's management system, in order to automize billing phases and the management of suppliers' orders.

A self-learning system guarantees fast and precise dosages. Process drifts are deviations from optimal production process parameters or any errors generated from the plant's mechanical parts that can happen during the process. The system is able to recover them in real-time and the new parameters must be applied to successive processes.

The system includes a production planning system integrated in the company's supply chain, from the customer's order to delivery.

A geolocation system is also available, which monitors the journey of the truck-mixer until its return to the center.

The software manages all the plant functions from PLC, through an easy and rational user interface, and control systems impede the execution of wrong functions.

The automation allows remote update of production mix, as well as programs' implementations and maintenance.

2.5.2 Features of the remote-control production plant

A plant which produces dry concrete when digitalized and automized achieves optimal management of the components of cement mixes and problems linked to the dosage and unloading.

The concrete loading point is optimized, thanks to the synchronized unloading system of the concrete mixer products, which with suitable solutions that modulate the speed of the unloading organs, distributes cement mortar uniformly on the whole quantity of aggregates, no matter whether the concrete has a high or a low cement dosage. This functionality guarantees homogeneity within the mixture in the concrete mixer, and it eliminates lumps that are formed during the loading phase, which penalize the mechanical strength of the concrete produced.

2.5.3 Raw-material supply

Raw-material management is fundamental for the control of the materials flow within the productive process. The system satisfies the company's needs regarding the management of raw-material entry and exit flows. Thanks to the system the company is able to know the stock situation and the availability of each item in real-time, in order to automatically elaborate supply proposals.

The lot traceability management tracks and controls each individual warehouse movement through identification and classification based on the lot to which they belong.

The software links the raw-materials production lot used in the production cycle of each load.

2.5.4 MIX design

The information obtained from the control of raw-material allows the firm to project suitable mixtures to produce goods required by the client, respecting certain requisites.

In detail, it works using:

- The raw-material analysis archive
- Selecting components based on economic information, supply distances, and collaboration with suppliers
- Laboratory tests and historical series of production
- Unitary recipes processing for each product, both following standard production and customer specifications
- Withdrawals and resistances recording, with timely reference to the load cycle
- Potential new design following the controls charts indications

Each individual recipe is kept in an archive.

2.5.5 Control system and predictive reporting

The control system fundamentally measures two topics:

- The monitoring of information collected from machinery
- The monitoring of the productive process (quality control)

Product control

To control the product, some statistics are provided, such as:

- Cumulative sums

- Single values and moving average control charts
- Mathematical method

At the same time, the average resistance and the standard deviation are verified for every single load or there will be grouped by families of concrete.

The aim is to intercept process drifts as quickly as possible and to the respect client's standards and/or requirements.

When the control system suggests changes it is possible to intervene in real-time, without the loading software operators' intervention.

Production Process Control

By elaborating information collected from processing cycles and from machinery, it is possible to obtain the production efficiency analysis:

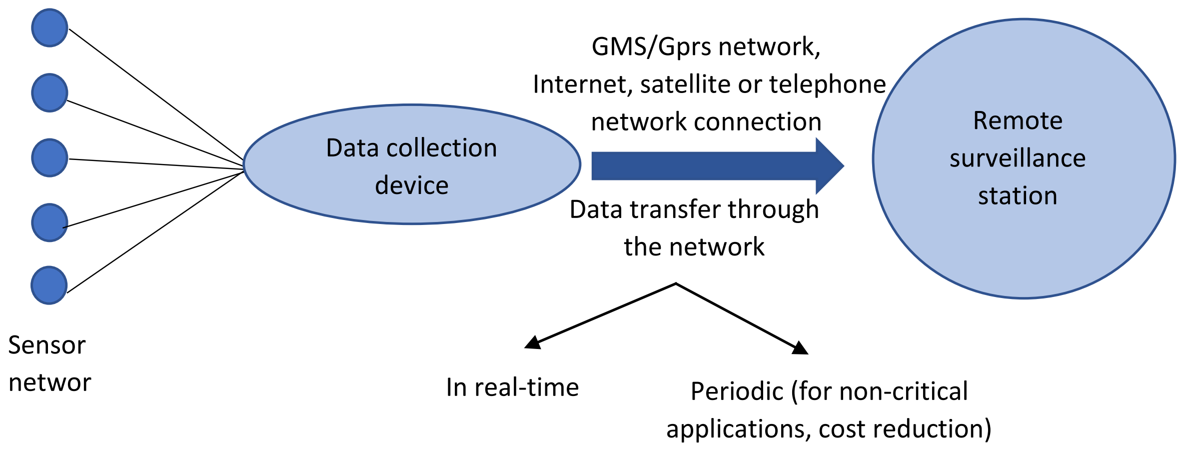
- By phase
- By machinery/work centre
- By employee

Periods analyzed can be chosen randomly, for instance: a single workday, a week, etc.

The supervision happens:

- **Continuous**, data collected in each process, and it is possible to intervene quickly
- **On-Line**, processing, analysis and potential diagnostics are performed in real-time during the process
- **Direct**, the phenomenon is directly observed, (for example, cement mixer anti-clogging probe)
- **Periodic**, data are collected only if an inspection is planned
- **Off-line**, the analysis happens when the machine is stopped, or *processing of data acquired during the process*

- **Indirect**, supervision through the observation of signals and quantity related to it



Some examples of real-time monitoring are: hoppers, aggregates, dust silos, and additives; loading water and water in the truck mixer process; outgoing consistency; loading water density; environment temperature and time cycle; stocks and materials consumption and energy consumption.

Operations that can be performed from a remote station are:

- Monitoring machine or plant health, thanks to acquired data
- Data integration in a company management system
- Alarms recognition and signals to report to plant operator or management and supervision systems
- Intervention planning (maintenance, inspections, etc.)
- Possible direct intervention in the machinery or on the plant through remote control
- Data registration to obtain operation and behavior trends
- Implementation part of programs

This work method allows the firm to apply four different maintenance strategies, based on possible causes and needs, to minimize errors and optimize the process. The reactive maintenance is an intervention due to damage or abnormal behavior. The preventive maintenance is a periodic intervention based on time-based schedules. Intervention based on the systems' state, which is possible to analyze thanks to the machine monitoring, is the predictive maintenance. Moreover, proactive maintenance is available to minimize or eliminate possible damage.

2.5.6 Technical specifications

When plants are automized main characteristics emerge:

- Aggregate, cement and water transportation and dosages can be personalized, as well as the concrete unloading and system parameters management
- Unlimited dosage formulas
- Work, formulas, parameter and consumption reports
- Allows different users, at least three, to have different access levels and authorizations
- Scheduled maintenance register
- Interconnection among IT factory systems with remote upload
- Interface with actual or future machinery of the productive phase
- Simple and clear masks are inserted between man and machinery
- Elevated parameters standard for safety, health and hygiene at work
- Monitoring of process parameters and adaptation of process drifts

2.5.7 Advantages

Advantages using this approach are many. It allows the continuous control of machinery or plant operation, traces the performance and production's historical evolution, and it has centralized supervision. It increases plant operation, thanks to undesired machine downtime reduction and better management of planned downtime. It is possible to achieve repairment and maintenance cost reduction, and performance maintenance above desired threshold, and anomalies and incipient damages prevention.

Thanks to all the economies underlined and to the economies of scale, it is possible to reach widely sustainable results especially related to the quality levels of the final product.

3.REAL CASE

A real case produced in Italy is presented below. A plant for the production of cementitious conglomerates with both wet and dry techniques. In the case described both the modernization and an extension of the existing implant, which included a single dry production line, are realized.

Photo of the plant during the assembly phase

3.1 PLANT 4.0

The existing plant was equipped with a line of three storage hoppers, a scale for cements, three cement storage silos, a batch of additives for mixtures. The plant was controlled by a pc workstation connected to an old generation panel for semiautomatic productions.

At this plant a new production line has been added, equipped with a continuous mixer for the production of premixed conglomerates, transportable both with truck and cement mixer truck (mix concrete).

The implementation included also the supply of three new storage hoppers. Thanks to a series of conveyor belts, both the old and new hoppers have been projected to serve both production lines.

A new silo, in addition to the existing one, is built for the storage of bituminous emulsions to be used for the production of mixtures based on recycled aggregates deriving from road milling (these mixed based on material from 100x100 from recycling, can be used for the realization of road foundations).

All the electromechanical parts are interconnected to the control panel equipped with PLC properly programmed. That in turn it exchanges information with the plant management program.

This exchange of information entirely happens on IP network, in addition a wireless network that covers an area of about 1500 meters has been realized, in order to allows to the firm the remote control of the production plant.

Parts (electromechanical devices, sensors, motors, valves, load cells, etc.) connected to the PLC are the following:

- Electronic weighing system with aggregate load cells
- Load cells APPROVABLE metrologically mod. STI 15000 with a total capacity of 60,000 kg in high precision class C3 developed in compliance with the OIML R60 recommendations
- Load cells APPROVABLE metrologically mod. STI 1000 with a total capacity of 3,000 kg in high precision class C3 developed in compliance with the OIML R60 recommendations
- Cylindrical cement dispenser 2000 kg. complete with frame
- Continuous mixer 450 t / h. 250 mc / h complete with flat canopies
- Screw ø 273 mm center distance 5000 mm. inclination 40 ° 90t / h. ball joint to the load with ø 350 mm flange. tube ø 273 mm. to the drain
- Screw ø 219 mm center distance 5000 mm. inclination 40 ° 40t / h. tube 273 mm. with edge for sealing rubber sheath on the load, tube ø 219 mm. with edge for sealing rubber hose at the exhaust

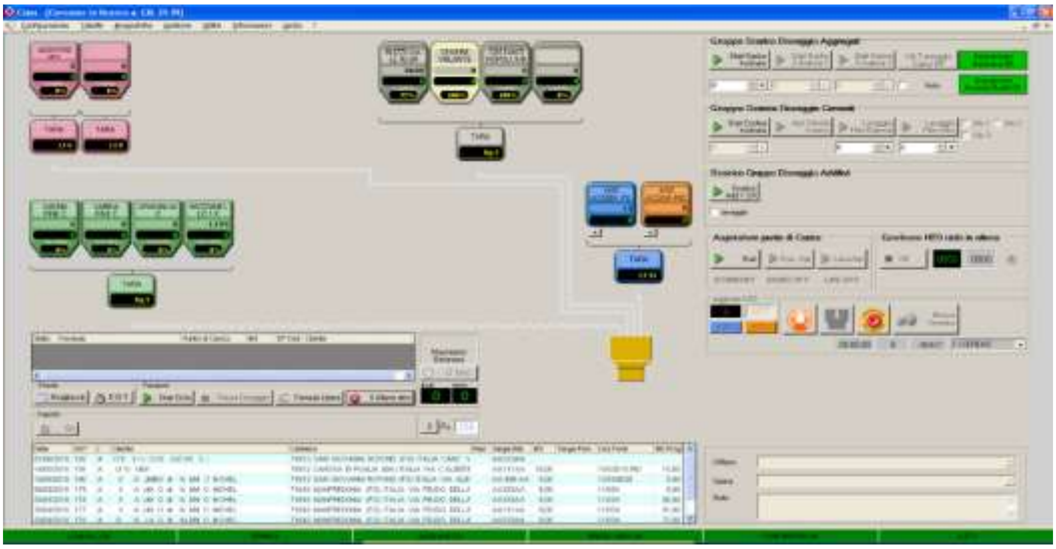
- Conveyor belt max. complete 22 ° inclination center distance 4000 mm. belt width 800 mm. frame in folded section, treated with galvanizing cycle according to EN ISO 1461. gear motor with orthogonal axes
- Conveyor belt max. complete inclination 22 ° center distance 9000 mm. belt width 800 mm. frame in folded section, treated with galvanizing cycle according to EN ISO 1461. gear motor with orthogonal axes
- Additives and liquids dispensers with weight system
- Probes for moisture inert detection
- Cylindrical cement cylindrical weighing scale 2000 kg. complete with: 300 mm discharge valve electronic weighing system. 3 square meter filter vibrator and pneumatic panel, all treated with galvanizing cycle according to EN ISO 1461
- Solenoid valves
- Measuring devices for magnetic water dosing
- Flush security systems for monitoring the operating perimeter of moving machinery with manual reset

Each component is connected with the contactor controlled by PLC.

Once mechanical and electromechanical are produced and/or modified, all components are connected to the PLC.

The plant is connected with the workstation installed at the company office always through the IP network.

The management software of the plant has an interface as the following one:



The possibility of the user to interact with all the plant's components and to carry out necessary choices to determine the single supply appears clear from the figure.

For instance, the user can decide:

- The customer addressee
- The MIX design
- The vehicle that will transport concrete
- Etc.

Alternatively, the user has the possibility to directly select a planning element under the "rough draft" voice (Figure 1). Each request corresponds to a productive cycle. All cycle data will be registered on specific tables of a database of the SQL Server type.

Figure 1 Planning

These tables will then be used to interact with others automations of the system, such as billing or reports (subject of the next paragraph).

Before activating the new plant, all the personalized parameters, related to storage hoppers, cement silos and additive dispensers, are set locally or from remote.

In addition, the program uses different preloaded master data, powered by local or remote interfaces.

Examples of master data are:

- Clients

- Destinations
- vehicles (concrete pumps, truck mixers, trucks) – Figure 2
- Drivers
- MIX design (figure 3)
- Raw-materials
    - Cements
    - Aggregates
    - Additives
- Etc.

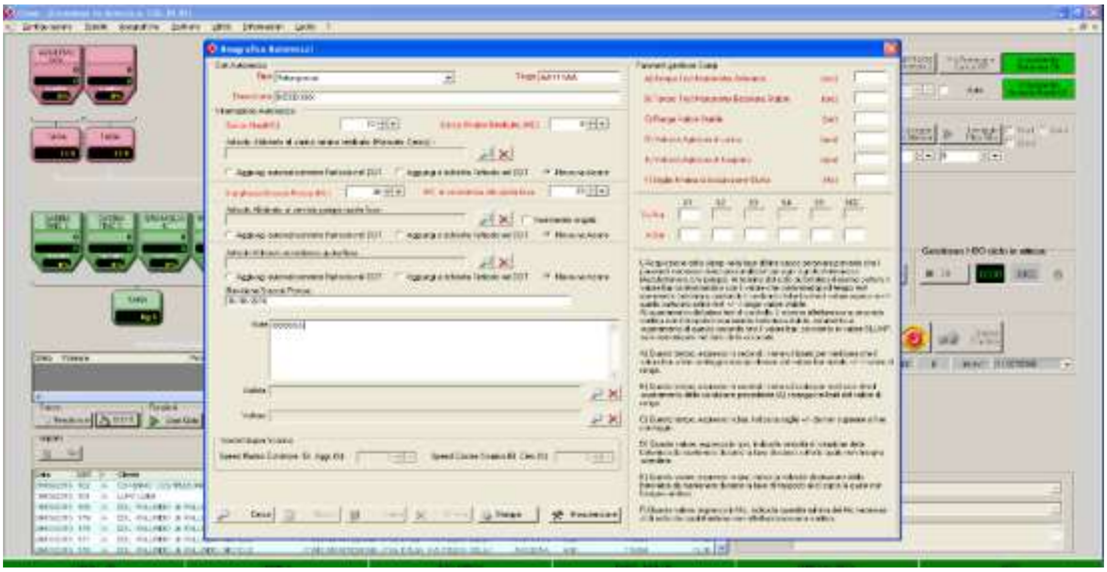


Figure 2 Trucks

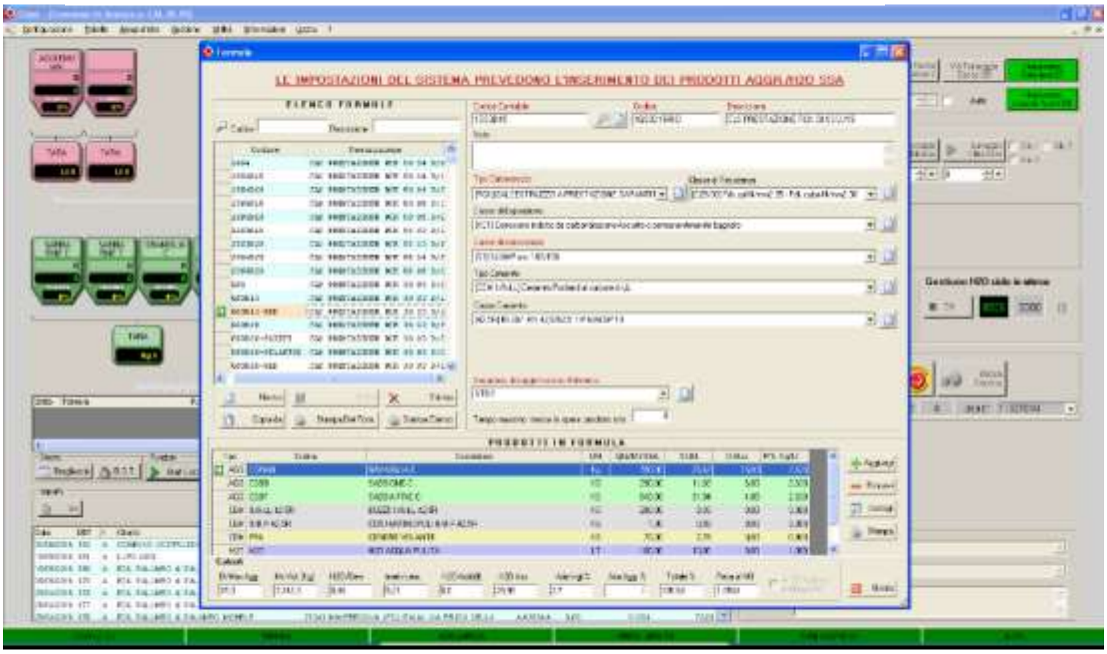
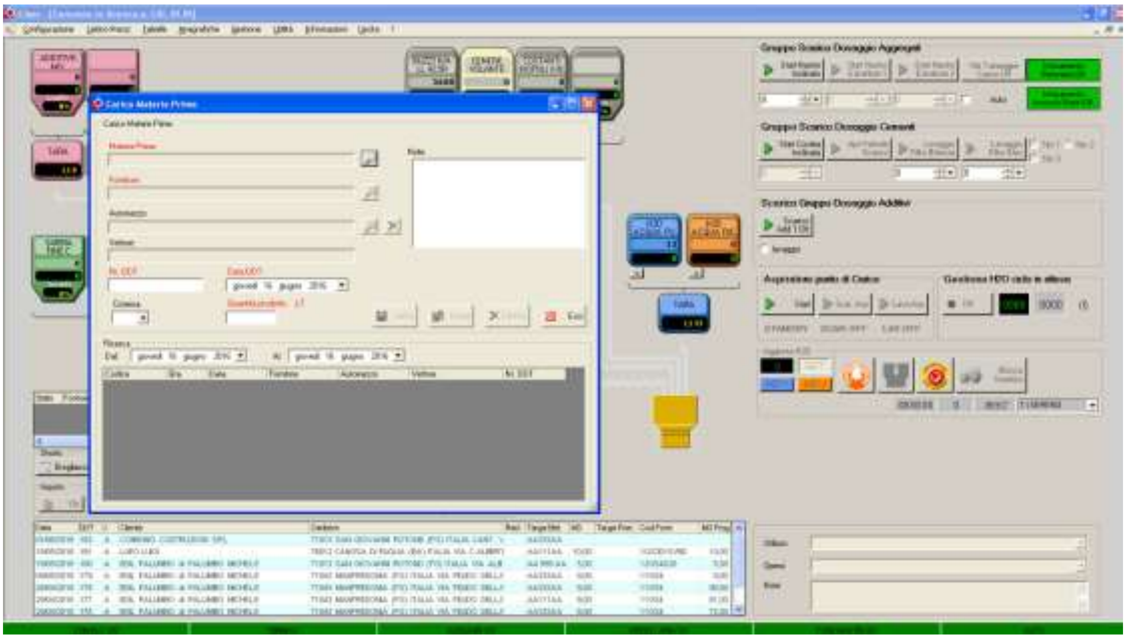


Figure 2 MIX Design

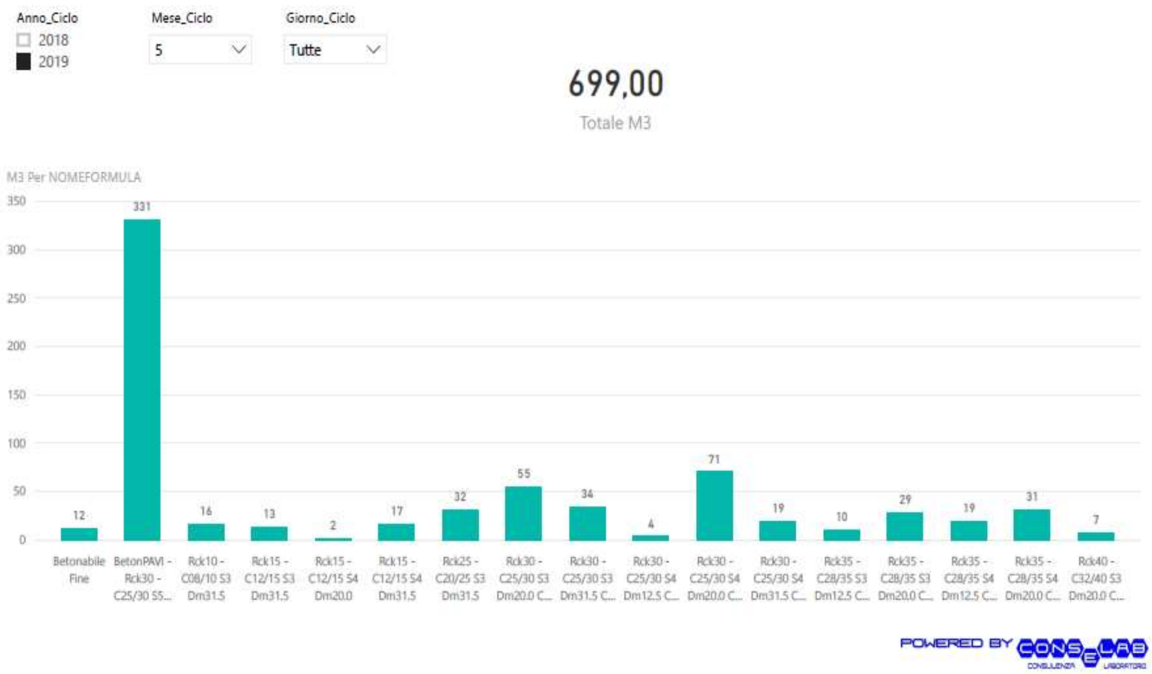
Follows the interface used for raw-material loading



3.2 POWER BI REPORT

Some report examples accompanied by a brief explanatory note follow. In particular the following graphics are described: sold by product, out of tolerance, KG/MC error vs MC, humidity per cycle and product, management of water and dosed vs correct comparison.

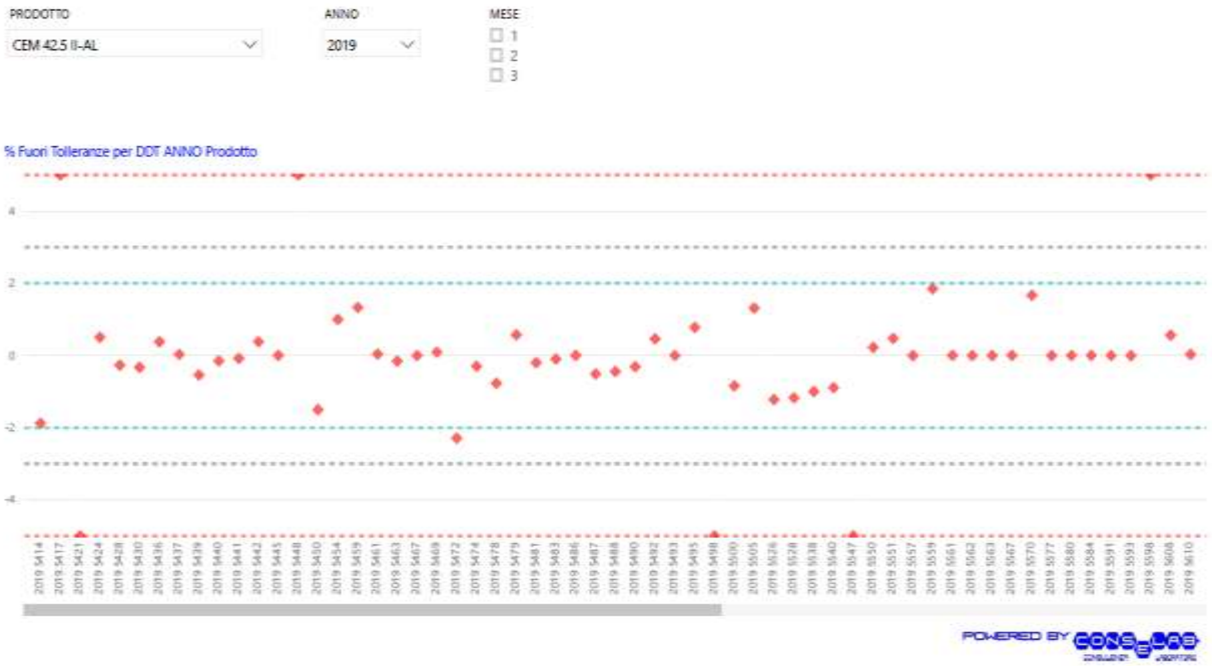
3.2.1 Sold by product



This type of report allows to the firm to visualize, from any device connected to internet,

product sold in a given period, using three filters: Year, Month, Day. All parameters are referred to table of cycles stored during the production.
Data report are grouped by products type (MIX Design). At the top the total of cubic meters (M3) produced in the selected period is reported.

3.2.2 Out of tolerance



The "OUT OF TOLLERANCE" report is one of the most significative and useful one form the products' quality point of view. Moreover, it is also useful to monitor the operation of the production plant. Observing this report the firm can also analyze in real-time some fundamental aspects also from the economic point of view (such as waste of cement).

As the table shows, each productive cycle is represented by a red point ◆ which corresponds at percentage of variation between the quantity expected by the MIX design and the quantity actually used in the single cycle for the raw-material selected (in the example the cement is 4,25).

In the graph are set lines which represent respectively:

- Line 0, the one of the correct dosage
- Lines +/- 2 indicate the company goal

- Lines +/- 3 indicate the goal according to the regulation
- Lines +/- 5 represent all the Out of Tolerance cases

Negative out of tolerance can bring to cycle waste, or in some cases to corrective actions.

When the out of tolerance are positive may lead in some cases to cycle waste, depending on whether they relate on inters, binders or additive.

As the graph shows, errors are quickly recovered from one cycle to another. If it does not occur, maintenance actions on the plant are necessary.

Techniques used by different automations, to carry out the recovery, can be subdivided into two categories:

- Tapping technique
- Automatic technique

The first one is the most ancient and most widespread. It consists in the dosage of the single raw-material based of successive approximations within the single cycle. Firstly, the unloading mouth is opened for a predetermined time, in general that does not reach the expected quantity, successively, the single raw-material is weighted, with a sequence of short opening at regular intervals, each evaluated by weight measurement tools. This technique allows the firm to obtain good approximations of MIX design, but it has the disadvantage of significantly increasing loading time.

The automatic technique is more modern and much more efficient. It is based on the evaluation of a series of parameters which take into account mainly results obtained by previous cycles. Good results can be obtained already after firsts commissioning cycles of the new plant, unless malfunctions, which require repairing intervention of mechanical components, occur.

These reports are acquired by a plant controlled by a system which uses the second technique.

The following report explained is another tool used to verify the good operation of the plant.

3.2.3 KG/MC ERROR vs MC

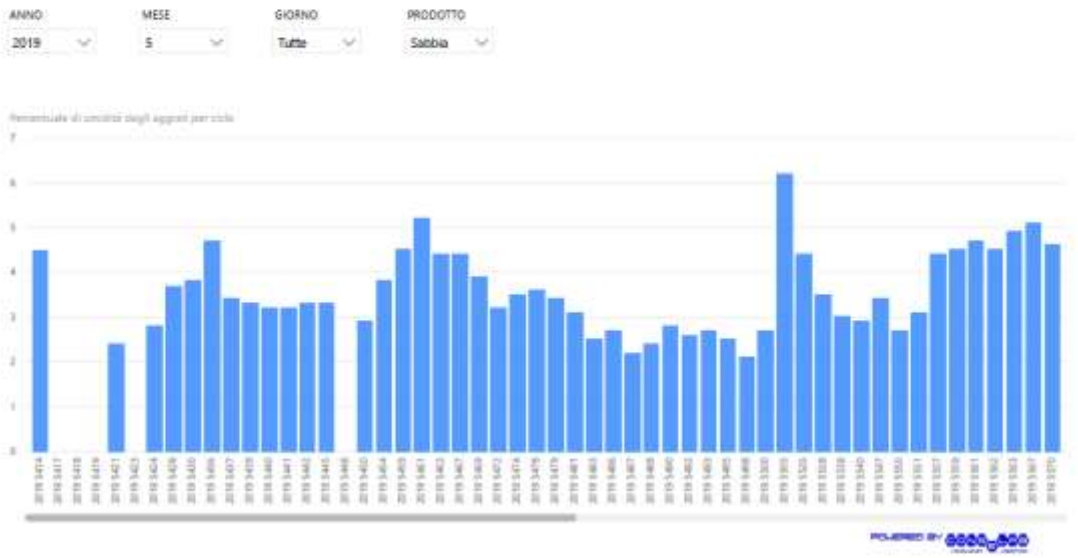
This report underlines the correlation between product's errors and quantity of a single cycle.

Generally, a concrete loading in a mixer truck exceed 5 meters cube and can go up to 10, for this type of loading the error, expressed in KG (a meter of concrete weights from 1.600 to 2.400 Kg) in the observed period and for the examined cement in the example, is more incisive for smaller loads and in any case very sporadic.

The following two graphs regards the management of a fundamental component, even though less important from the economic point of view, that is the water.

The first report deals with the issue of humidity present in inert raw materials.

3.2.4 Humidity per cycle and product (raw-material)



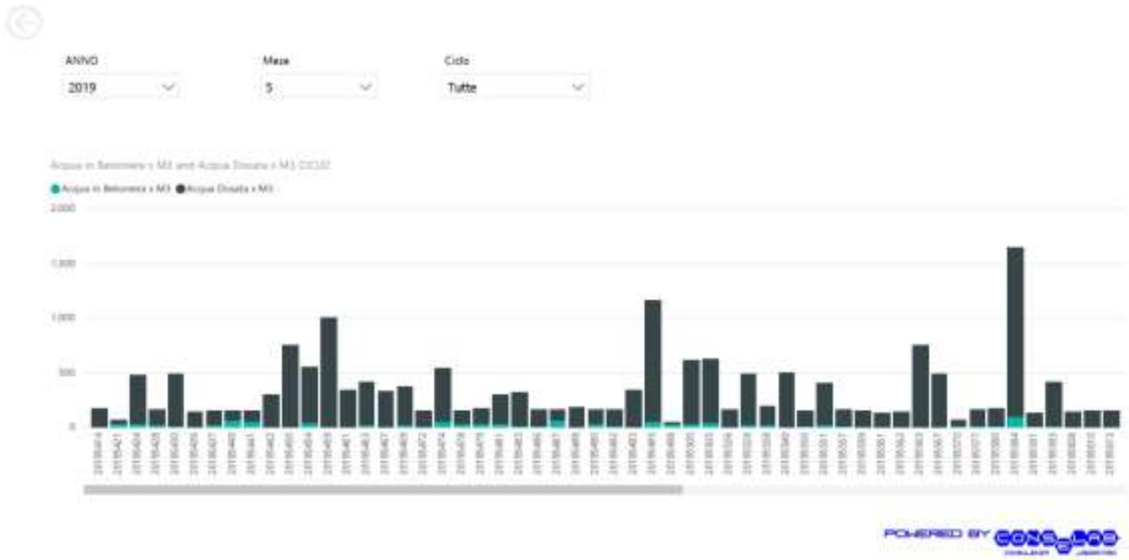
Here four filters are used, in addition to those already present in other reports it is possible also to select a single production day.

As the plant description underlined, particular sensors exist, usually at least one for storage hoppers. Sensors that can evaluate humidity present in inert aggregates (sands, rubbles, etc.) are the “humidity probes”.

The automation of the plant will apply an adjustment of quantity of water to be introduced into the concrete mixer truck or, in the case of WET type systems into the mixer, based on the humidity percentage detected.

The next graph, always related to water, makes understand that the potential presence of water in the concrete mixer truck must be evaluated before starting the single production cycle, only on vehicles equipped with special devices it can be automatically detected.

3.2.5 Management of water



For each single cycle, water present in the mixer truck (green) and the one added successively (black) is indicated.

The last report is a pie chart, it is useful to obtain immediately a comparison between expected results and obtained ones, in terms of dosage percentage of raw-materials, in a rather extended observation period or in a single productive cycle.

3.2.6 Dosed vs correct comparison

In the reported an example of the DOSED VS PRODUCED comparison in the month of May of the current year, even without reading individual percentage value, a qualitatively efficient behavior of the plant is immediately detected.

CONCLUSION

In the first chapter current results of innovation in 4.0 field in different sectors are reported. From this study emerges that not all sectors offer the same improvement perspective also in relation to the previous level of IT. Given the economic importance of construction sector (first in Italy and in the rest of the word for revenue), the focus of the analysis is on this specific sector, in particular on one of the principal products: concrete.

The use of digital technologies in firms which produce cementitious conglomerates is considered the best practice to obtain high quality standards. Especially since in this field modernization and/or revamping activities can be carried out even with limited investments.

In fact, also in new plants production the cost increase is limited, as long as firms are already equipped with IT management system.

Italian regulation and tax benefit allow firms to:

- Recover as a tax credit costs necessary for the preliminary analysis of technological innovation (R&D activities)
- Obtain approximately 60% of costs in form of tax deductions (IRES), through the revaluation envisaged for purchases compatible with the criteria of the Industry 4.0, obviously when there are good prospects for turnover during this amortization period.

This essay underlines that economies offered by 4.0 investments grant also other forms of economic improvements, thanks to the waste reduction opportunity (products guarantee a better performance), and resources optimization: raw-material, quality of work. Obviously, the process respects the mandatory requirements of real-time recovery of process drifts.

A plant 4.0 simplifies the management also in terms of environmental compatibility and, as mentioned, this type of plant allows to the firm illimited possibilities of MIX design production, including also aggregates that came from C&DW.

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