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Artificial Intelligence in the Automotive Industry:
PP&DS Optimization

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Summary

The purpose of this thesis is to give a deep understanding of the manufacturing revolution regarding the industrial internet of things and the application of the artificial intelligence in the automotive industry with a concrete case study.

The elaborate passes through the literature and the economic forecasts, which provide the analysis of the disruptive technologies and the supporting Government plans in different countries.

The first Chapter shows the objectives of the thesis and the goals and limitations associated to the technologies of the fourth industrial revolution.

In chapter two there is the history of the main organizational phases which characterized the evolution and the development of the industry 4.0. It passes through the Lean Management and the value stream mapping.

The Lean Tools and their applications are explained in order to make the lector comfortable with the theories and the reasoning behind the innovative ways of production.

Chapter three is focalized on the industrial internet of things, there is the analysis of possible future development and the perspective's growth of the model, with a focus on the connected workers and connected machines which are the main examples of the IIOT use in a plant.

The case study is in Chapter 4. It shows the analysis of a use case really developed in Accenture, where thanks to the help of a startup, there is the implementation of an algorithm for the production planning optimization.

There are four main actors involved in the case: a consultancy company, a corporate, a startup and an innovation hub which cooperate in order to get the result by saving money and time.

The methodology used to carry out the project is the agile approach for the rollouts and a waterfall one for the pilot, so that the substantial differences can be noted.

The thesis ends with the benefits and the next steps which the technology could have in the specific corporate in the following years. The final part wants to underline the possibility of future developments of the case, it would just be the false end of an elaborate, which shows the ladders that could be performed in the subsequent periods.

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La parte dei ringraziamenti è sempre la più difficile da comporre.

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Abstract

The purpose of this elaborate is to give a concrete understanding of the application of an open innovation strategy; how a consultancy firm can work for an important firm in the automotive sector and rise benefits thanks to the alliance with startups and researcher associations.

It is demonstrated by a case study based on an algorithm for the production optimization in a plant.

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Chapter one

Literature

Industry 4.0, otherwise known as Industrial Internet of Things, is a government program (defined for the first time in Germany), which introduce the fourth industrial revolution and boosts the firms to create the *Smart* factory. We can enumerate three industrial revolutions: the first one in the XVIII century, characterized by steam or coal machines and by the born of first industries; the second in the XX century with the electricity, petrol, mass production and the third one in the 70s, afterwar, with the introduction of information technology, so the computer, electronics and tools for the production automation.

Today we are at the edge of the fourth industrial revolution involving intelligent and interconnected products and processes. Smart Manufacturing is defined not only by innovative technologies but also by new business models to which these technologies can be applied, identifying the way in which it can generate value for its customers.

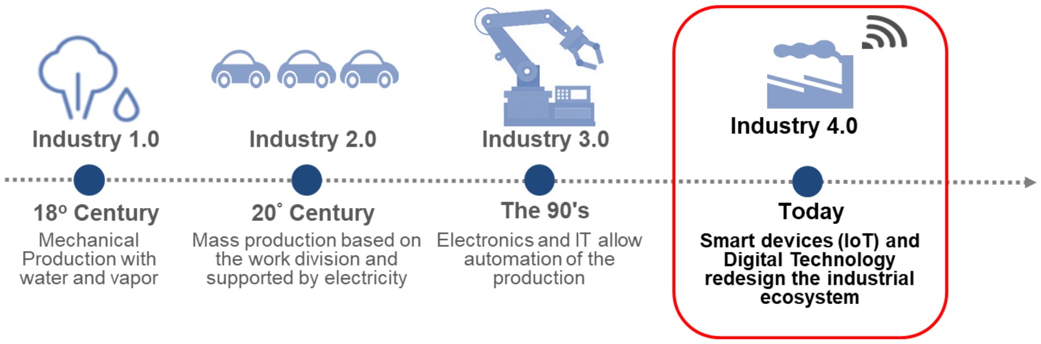


Figure 1. 1 The four industrial revolutions

We do not know exactly the date nor the year in which the fourth industrial revolution began, but we know the technologies which enabled it. We can see in Figure 1.2 how each innovation is directly connected to the Artificial Intelligence.

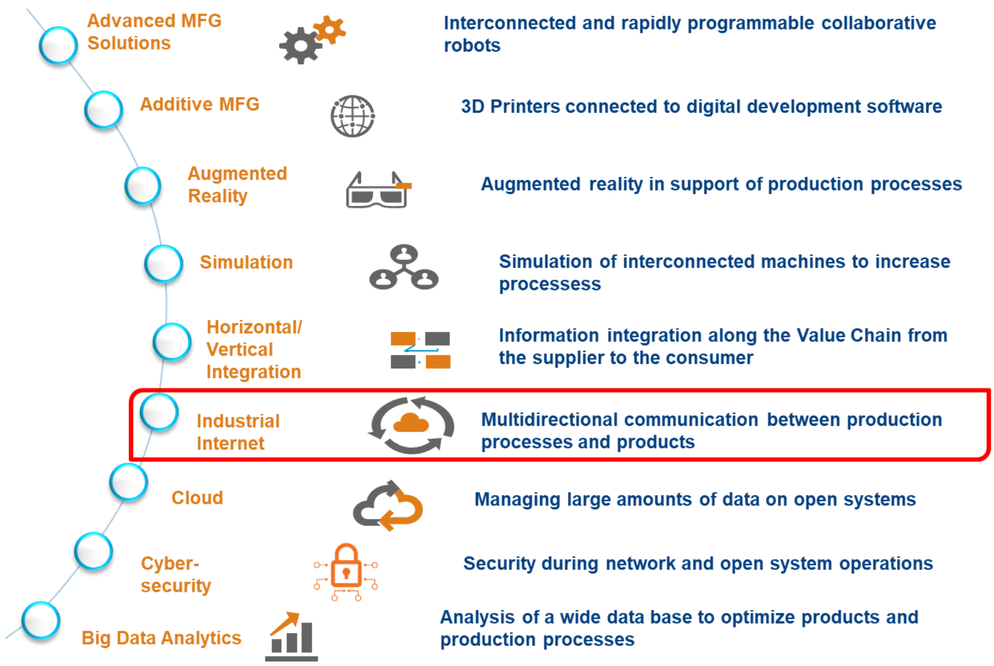


Figure 1. 2 I4.0 Enabling Technologies

The IIoT - Industrial Internet of Things - has a global impact and it is estimated in a value grow from $2.99 Trillion in 2014 to $8.9 Trillion in 2020, with a CAGR – Compound Annual Growth Rate – of 19.92% (Louis Columbs, Forbes 2018). Accenture and Frontier Economics have analysed 20 emerging economies (Australia, Brazil, Canada, China, Denmark, Finland, France, Germany, India, Italy, Japan, Holland, Norway, Russia, South Korea, Spain, Switzerland, England, United States) and global GDP coverage of $ 10.6 trillion until 2030. With more investments on IIoT technologies, an increase of 14.2 trillion of GDP can be achieved. (Purdy & Davarzani, 2015)

Gartner recently estimated that through 2018, “80% of IoT implementations will squander transformational opportunities” and fail to monetize IoT data. In this era of extreme data management, IoT data engines must address massive sets of complex data at unparalleled speed, with streaming data analysis, visual foresight, and streamlined machine learning, all orchestrated around an innovation-focused ecosystem. Without these things, it becomes impossible to support, utilize or monetize the IoT. (Forbes, March 2018)

According to a 2017 IoT manufacturing survey, forty percent of manufacturing enterprises are currently in the process of implementing IoT initiatives, and 46% currently have IoT initiatives in place under the umbrella of Industry 4.0 and smart manufacturing initiatives (see "Use Models to Accelerate Your Industrie 4.0 Initiative") Gartner 2018.

“Manufacturing’s adoption of IIoT, smart factories and comparable initiatives are powerful catalysts driving AI adoption. Based on the proliferation of (IIoT) devices and the networks and terabytes of data they generate, Accenture predicts AI will contribute an additional $3.76T GVA (gross value added) to manufacturing by 2035. Supply chain management, forecasting, inventory optimization and production scheduling are all areas AI can make immediate contributions to this industry’s profits and long-term economic” (Forbes 2018)

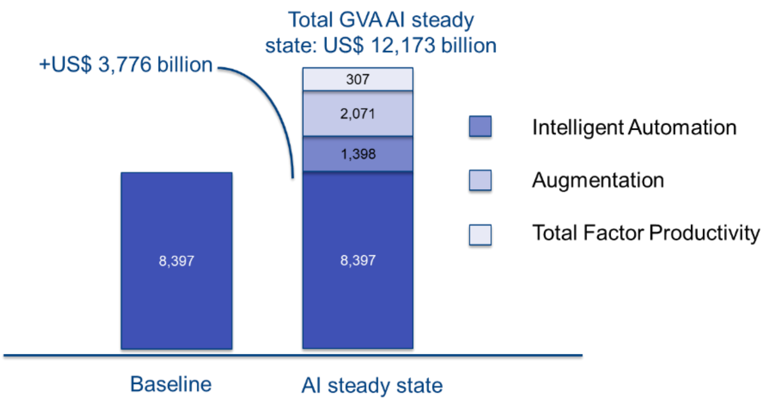


Figure 1. 3 Source: Accenture and Frontier Economic

The best potential for value creation will be in optimizing the operations of the various factory processes in order to make them more efficient.

Using sensors and actuators, you can significantly improve the degree of utilization of assets and therefore productivity, determining when the machine needs maintenance to prevent breakdowns and save the costs of routine maintenance.

Remote control, tracking, control of machinery and workflow can lead to additional savings, including energy savings of at least 10%.

The need for a new industrial paradigm derives from the employment data of the previous four years in Europe: from 2008 to 2014, 4.3 million jobs were lost in Europe, of which 1.8 million only in Italy (Draghi, 2014). It is therefore essential to formulate new growth strategies and promote employment and well-being of our country. For Germany, a successful transformation of the manufacturing sector could lead to the creation of 7 million jobs. (Brettel, Friederichsen, Keller, & Rosenberg, 2014)

Are the professional figures leading to this growth only engineers?
No, they are not. The fear of losing more jobs due to increasingly intelligent devices and leaving space only for highly qualified personnel can be overcome thanks to the principles of operation of these tools. In fact, these are smart devices and that are increasingly intuitive and easy to use by everyone.

According to the World Economic Forum, Smart Manufacturing will go through four phases:

- Phase 1: operational efficiency and capability assessment that will imply a significant increase in productivity
- Phase 2: new products and services, development of pay-per-use models which enables you to pay what you use, no longer the product
- Phase 3: outcome Economy, i.e. we will pay for the result obtained by exploiting interconnected ecosystems
- Phase 4: pull Economy, End-to-End Automation, Circular Economy

"Circular economy is therefore a system in which all activities, starting with extraction and production, are organized in such a way that someone's waste becomes resources for someone else" (Webster, 2015)

It is therefore necessary that the industry tries to experiment in such a way as to understand the added value deriving from the use of these technologies, gradually moving to involve the whole ecosystem of factories and manufacturing companies. (Liongosari, Mullan, & Müller, 2016)

Figure 1. 4 Circular Economy

1.1 Disruptive technologies

Today we are talking more and more about disruptive technologies. But what does the word disruptive mean?

The disruptive innovation theory was introduced by Clayton Christensen, of the Harvard Business School, in his book "The Innovator's Dilemma" (1997) Christensen used the term to describe innovations that create new markets by discovering new categories of customers.

This is partially possible by exploiting new technologies, developing new business models and leveraging old technologies in new ways. Christensen contrasts disruptive innovation with sustaining innovation, which simply improves existing products.

Today there are new technologies, new waves of technological renewal that are bringing epochal changes in all industrial sectors. For example, there are self-driving cars and airplanes, pharmaceutical devices created tailored to the patient, soon there will be medicines tailored to the individual person, plants that self-optimize, taking into account the boundary conditions to always have the best performance, machines for coffee that recognize fingerprints understanding instantly how the customer wants coffee, sensors tattooed on the skin, machines that make themselves or ships that can be led by captains who are in port to overcome sea sections at high risk of piracy.

This means that in all sectors there are companies that, by developing new businesses, bring an epochal disruptive innovation.

Companies that have a less reactive drive towards innovation feel a lack of security because they need to innovate, change their business and their value proposition to face the future.

Companies need to think about how to evolve, trying to figure out how to make the most of technology. And these technologies do not just transform what operators, customers, suppliers do, but also transform the way these actors operate.

In order to do this, you need to be able to digitalize your processes and your company.

Digitizing does not mean using digital but metabolizing the fact that digital information can be used differently. Companies must not only resort to a digital product thinking they have innovated, but they must understand that digitization opens a whole series of possibilities that must be managed by an IT infrastructure suitable for allowing the maximum exploitation of all information.

The McKinsey Global Institute has identified 12 technologies that could drive economic transformations in the coming years:

The published report explains that the combined application of all 12 technologies, including advanced robotics, energy conservation, mobile internet and cloud have an impact between $14 trillion and $33 trillion per year in 2025. (Manyika, et al.)

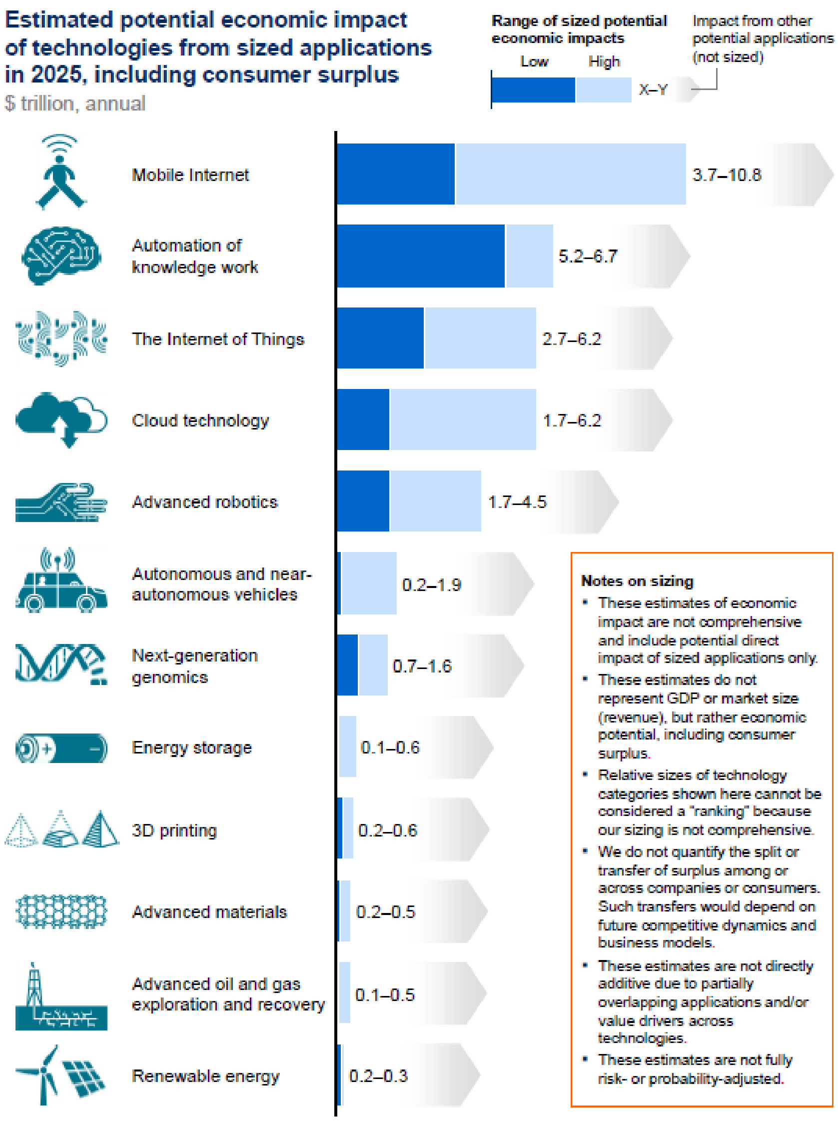


Figure 1. 5 Disruptive Technologies impact. Source McKinsey Global Institute

This structure must allow the development of "Smart Innovation" to start, then move from concept to use, creating a single environment in which all users are involved, have the right information, correct and in the right quantity, now and in the appropriate context.

The models must contain the intelligence needed to ensure that posthumous use of the information collected can be useful to future operators to understand how and why a particular operation was carried out.

The products can be designed, tested and realized virtually before being made physical so that from the first batch of production you will have an object that is exactly how it was designed and how it should work.

Moreover, today the manufacturing industry has a poor ability to communicate and collaborate with plants located in different geographical areas and the lack of global visibility of production sites, causing inevitable delays and downtime.

There is the need to analyse and collect a large amount of data from sensors, using Predictive Analytics.

What are the new business models, new industrial ecosystem and economic growth generated by the Industrial Internet? How the work will change with the automation increase and what kind of skills will be required? Also, how can governments and companies better respond to the next changes? Some key points are: create new products and services, renew and create value, transfer and create value in industries, monitor effectively, redefine processes, data and infrastructures and changing the way to work. It is possible thanks to cloud, connectivity, sensors, real time analytics, and investments of huge IT industries. The factors that impede the evolution are instead safety, legacy OT and infrastructures, interoperability, privacy, new investments and risks. The main developing areas of the IIoT are Manufacturing, Energy, Transportation, Public sectors and Healthcare.

The data obtained, in fact, are analysed in such a way that they are statistically valid and are used to construct, through advanced analytics, the forecasting models to be applied to remote diagnosis and collaboration tools.

It is possible to combine a top-down approach with a bottom-up approach, first analysing key macroeconomic factors and industry trends and then conducting further analysis on specific sectors. It is therefore possible to identify activators and inhibitors of the development of the Industrial Internet, while identifying opportunities and break points.

By focusing further on production, it is possible to list the problems to which companies are constantly resolving:

- Reduce the industrial costs of the product
- Maintain high quality standards constant over time
- Implement sustainable processes
- Implement lean processes in which all sources of waste are eliminated
- Meet market requests as quickly as possible
- Speed up and improve decision-making

To properly guide decision-making and create added value in factories, it is essential to identify four fundamental points: (O'Halloran & Daugherty, 2015)

1. People

2. The assets

3. The data

4. The way in which these three parts of the industrial ecosystem can be connected

The greater the complexity of the model, the greater the potential economic value deriving from it increases.

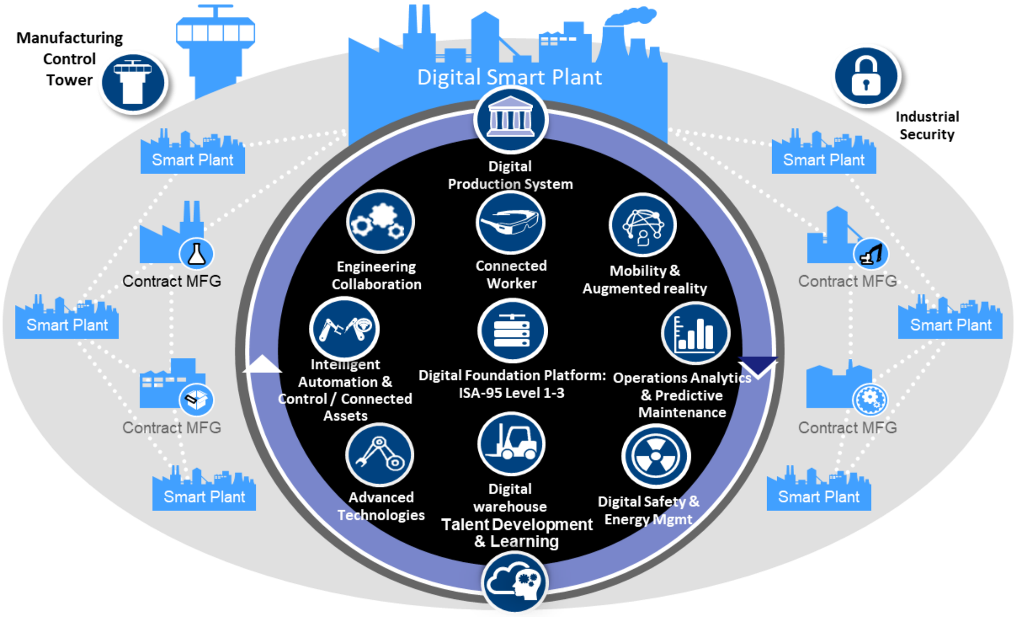


Figure 1. 6 Vision of a future Digital Smart Plant

Six are the levers of work to focus on to be competitive and improve the efficiency of industrial assets. (Proverbio, the six strategic levers to optimize the productivity of plants and industrial assets, 2015).

1. Technology: introduction of intelligent technologies and automation. Use smart devices to be provided to the operators to carry out important, fast, safe and sustainable activities related to the management of industrial assets (e.g. predictive maintenance, on-board operational maintenance, safe working procedures, intervene on machines and plants in fast way and by decisions taken at Central Control Tower level)

2. Visibility: extended accessibility of the systems by creating an inter-structural connection of the assets that allow different levels of the company to visualize the performance of the machines and plants with different types of indicators (e.g., EOI, machinery efficiency, labor, quality control, performance management of plants distributed in various areas of the globe).

3. Flexibility: it is very important to have plants that are flexible. It is essential to have standards in terms of industrial assets that allow moving materials from one factory to another, even if they are in different geographical

locations, depending on market requirements or allow the production of different products on the same production line

4. Skill: staff training; people are the most important asset that companies have available, so it is essential to invest in increasing workforce and knowledge

5. Operational Excellence: to make people multi-purpose in such a way that they do not have a crystallized operator focused in one position but operators who can be dynamically exchanged in the various types and phases of the production process, underlining the importance that the person has in organization

6. Lean Manufacturing: implementation of Lean projects dedicated to the optimization of production processes, the elimination of losses and

projects to stabilize and improve the production process through Six Sigma methodologies. The desire to implement these projects stems from a common feeling that is to report the production that has been given in counter work to the countries of the Far East, in Italy. So, if you want to bring production back to the factories, they should be re-engineered by applying Lean and Six Sigma methodologies.

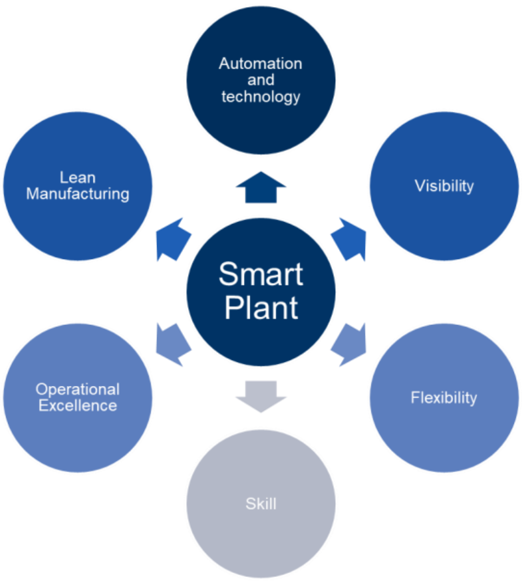


Figure 1. 7 The six strategic levers

Are we connected enough today?

This is the Smart Plant and there is the possibility of creating a digitally interconnected system, by connecting the four functions of the ecosystem

- Production
- Supply Chain (Production Planning and Logistics)
- Maintenance automation and Technology
- Environment and safety

Are companies ready to take advantage of this positive moment by first exploiting the greatest overall competitive advantage?

1.2 Government plans

Government plans are supporting Industry 4.0 worldwide: in the United States, there was in 2013 a plan for the Smart Manufacturing, where a network of institutes and excellence Lab were promoted by the Government and financed by public partnership – private public commitment. The institutes consisted of large private group ICT and university were involved for the technological and competences diffusion.

In Europe, there is the Plan Junker (2015-2020). EFSI extension (European Fund for Strategic Investments) with Target ~ 500€ Bn until 2020. ~ 1,1€ Bn are earmarked as a guarantee fund to encourage private investments, banks and public administration.

Germany *Industries 4.0 (2012)* were federally sponsored by action plan with the involvement of large industrial and technological players. The public engagement ~ 1€ Mld.

In Italy *Industry 4.0 (Piano Calenda 2017)* Subsidize private investments for goods and technologies I4.0. It consists in:

- Hyper-depreciation: Rate increases to 250% for goods I4.0
- Super-depreciation: Refinement and extension of the regulation for one year and Capital Goods: Extension of the regulation for one year
- Rotary Bottom Companies: FRI section dedicated to investments I 4.0 where CDP intervenes in pool with the banking system
- Encourage the development of new digital skills
- Skills 4.0: 400 million euros per year to be allocated to the higher Technical Institutes with the aim of reaching at least 100mila students registered by 2020 (in Italy currently Its students are about 9000 against almost 800mila of Germany)

- Increase private spending in Research, Development and Innovation
- Competence Centre: Building a real national network for the development and transfer of digital skills and high specialization
- Tax Credit for research: Rate increases on internal research from 25% to 50% and maximum taxpayer credit limits

DEPR. REGIME	CATEGORY	GOODS
Hyper-depreciation regime (250%)	Computer-driven or sensor-actuated 'Instrumental Goods'	Machinery and equipment for: • Plant logistics and warehousing • Manufacturing • Assembly • Packaging
Hyper-depreciation regime (250%)	Quality Assurance and Sustainability Systems	Systems and devices for: • Process and machine status monitoring • Product QA • Traceability • Energy consumption measurement • Pollution monitoring

DEPR. REGIME	CATEGORY	GOODS
Hyper-depreciation regime (250%)	I4.0 devices for human-machine interaction and workplace safety	Systems, devices and plant furniture for: • Supporting workers tasks • Increasing plant safety (e.g. wearable devices, virtual reality)
Super-depreciation regime (140%)	Intangible Goods related to Tangible Goods Investments in I4.0	Software, development and system integration

€ 1M Investment example

Super-Depreciation 140% of invest. cost — Depreciable value 1.400k€

Data in k€	Y1	Y2	Y3	Y4	Y5
Depreciation	280	280	280	280	280
Tax shield[1]	67,2	67,2	67,2	67,2	67,2

Total Tax Shield 336k€ 33,6% of invest. cost

Hyper-Depreciation 250% of invest. cost — Depreciable value 2.500k€

Data in k€	Y1	Y2	Y3	Y4	Y5
Depreciation	500	500	500	500	500
Tax shield[1]	120	120	120	120	120

Total Tax Shield 600k€ 60% of invest. cost

Source: Ministero Sviluppo Economico, European Commission
1. 2017-27, excluding further refinancing of the Guarantee Fund and Made in Italy plan

Figure 1. 8 Piano Calenda 2.0

1.3 The objectives

The main objective of this Thesis is to identify and describe the necessary tools for the application of disruptive technologies in a plant. The detailed tasks of the research are:

• Conduct a complete literary review and analyse the state of the art on Lean Manufacturing and Smart Devices;

• Formalize the process by which the company develops its Smart Manufacturing idea

• Map the resources and necessary tools to optimize the production process

• Conceptualizing the success factors of the development process of a Smart Plant

• Generate the indispensable models to exploit Smart Manufacturing

• Map the essential resources and tools to optimize the production process

• Conceptualizing the success factors of the development process of a Smart Plant

• Generate the indispensable models to exploit Smart Manufacturing

• Present conclusions on the significance, reliability and validity of the study results, discuss the theoretical, empirical and practical implications and present suggestions for future research.

It will be necessary to empirically test the models on selected companies in order to validate them and test their feasibility.

1.4 Goals and limitations

The analysis of the state of the art and the tools used by the companies shows that these technologies are not yet fully mature.

One of the most obvious problems today is that these technologies, which should be connected, are not. Added to this is the need to ensure appropriate training for staff to allow the appropriate use of these new tools, exploiting their potential.

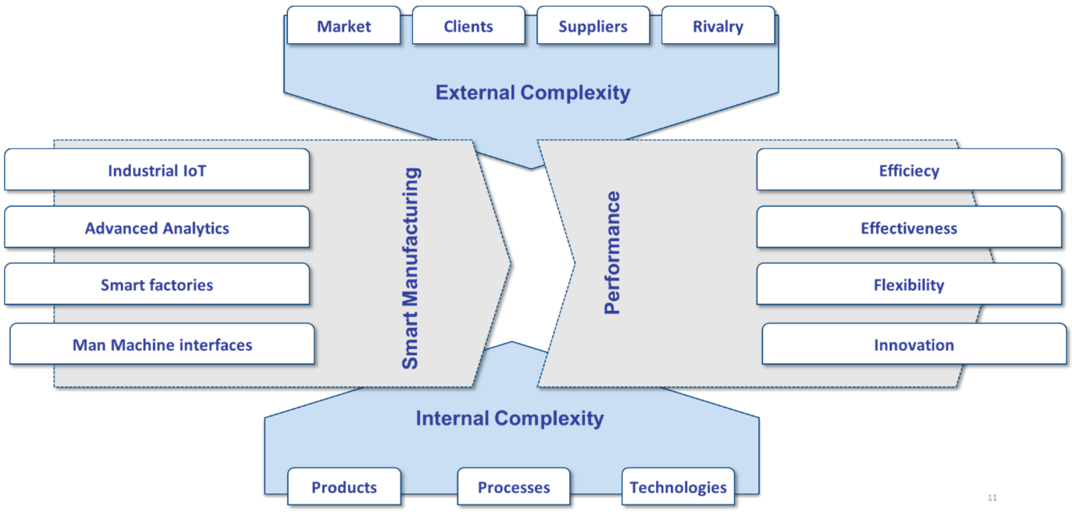


Figure 1. 9 Factor's complexity

Today external complexity is increasing because we are talking about new markets, markets with new customers, customers with new needs, suppliers to be integrated along the line.

All these innovations have an impact on the company and the latter consequently reacts by increasing its internal complexity. It is therefore necessary to invent new products, new processes, new technologies.

There are four types of services essential to address the Fourth Industrial Revolution:

- We must be efficient, that is, doing things in the fastest and best way possible

- Being effective or doing the right things
- Be flexible
- Be innovative

These four performance classes require a new lever that was not there before: Smart Manufacturing. The latter helps us to connect the tools typically used in industry, monitoring the assets in order to control the performance and organize the maintenance.

We try to construct bidirectional man-machine interfaces, in such a way as to no longer have a software programmer writing a code that the machine executes, but of the primitives that the machine itself, independently, can manage.

The technologies are therefore all known and already developed but what we are looking for will be done in the future and it is what the world will ask. Smart Manufacturing is not yet in the mind of the client, operators and managers, so you do not have the complete reading key.

The challenge of the industry today is to properly manage complex instruments, exploit their potential. The risk is of not being able to cope with the complications inherent in these operating and business models created to understand the reality that it is necessary to study, understand and analyse.

To overcome this challenge, it is essential to find the paths that help to apply functioning and optimized models.

The purpose of this thesis is precisely to build a model and the relative path necessary for companies to build their Smart Plant.

1.5 The approach and the method

The lack of research in the specific field of the creation of a Smart Plant highlights the question of what the most appropriate research approach is.

This research began with the aim of building a series of relationships between the company's human and productive resources and their performance, through a literary revision and a subsequent quantitative survey. As will be seen, quantitative research would not have been of value, if not supported by a solid and well-structured interpretative model.

Therefore, a more explorative and qualitative research approach has been adopted, reviewing the literature even more extensively and in depth, and interacting with sector experts - Entrepreneurs, Managers, Senior Advisors, Plant Managers, Operators, Professors and Researchers.

After defining the hypotheses, the sample companies were chosen on which the model was tested and validated.

The participation in Workshops focused on this theme was fundamental in which it was possible to listen to the expert opinion and evaluate how companies today are ready to face this change.

In the part concerning the definition of use cases, it was then essential to contact the manufacturer of machinery, dealers and visit some customers in order to define the real needs of the operators. Visiting the workshops, closely observing the machinery and analysing the projects, the technical sheets and the components, it was possible to construct an effective model of predictive maintenance.

Chapter Two

Lean Management

During the period of economic growth of the last century, the Fordist manufacturing system dominates the organizational models of the world industry. In this period of strong productivity, the only goal was the reduction of costs through the creation of an increasing number of products with equal resources involved. The production line moved at a constant speed and married the logic of "the more I produce, the more I sell". There was therefore a strong compression of the active intelligence of the operator who always performed the same movements by operating on high quantities of goods subsequently accumulated in the warehouses.

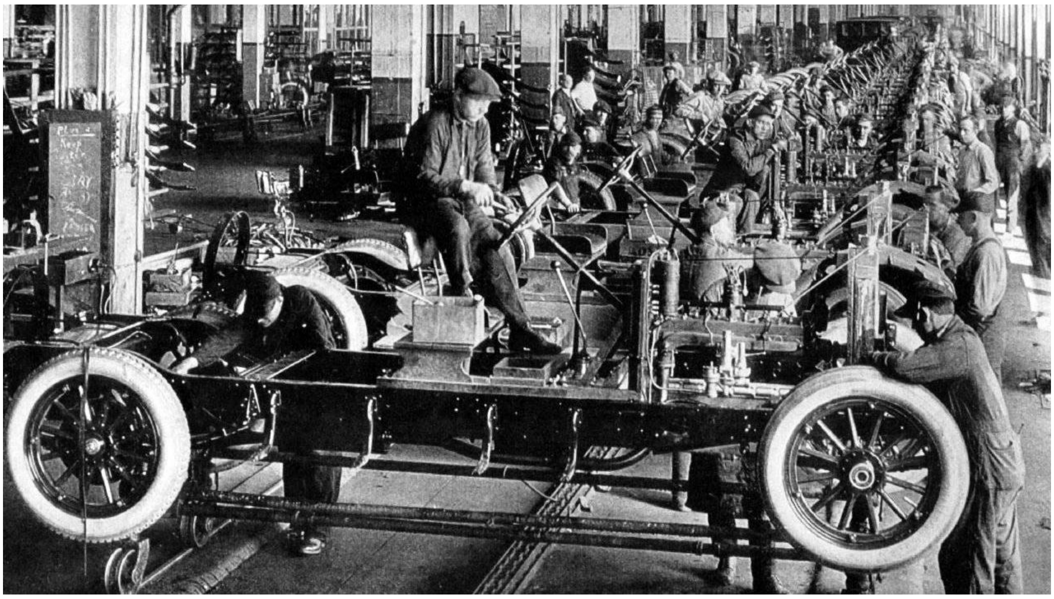


Figure 2.1 The Fordism

This system, solid in a period of great economic boom, collapsed under the weight of the oil crisis of the '70s, as it was unable to cope with the demands of a variable market. Then, from the "ashes" of the Fordist system, a new organizational model was born: the Toyota Production System.

We are soon witnessing a complete overturning of the perspective of the great American industries. Now the production cycle starts from the customer, it is modelled adapting to its needs. The guarantor of the correct functioning of the line is the worker who actively participates in the process. The idea of the "integrated factory" was born, understood as

"A unified and homologated factory community, in which the worker must consciously and voluntarily" dissolve "his / her intelligence in the work process, combining executive functions with control and design performance, reporting defects in real time and participating directly in the redefinition of the structure of the working process itself in relation to variations on demand."(Revelli, 1993)

The modern factory aims to create a sense of belonging in order to build a collective identity and knowledge within the company. The knowledge and experience of everyone are a fundamental resource to be able to cope with the vibrations of the market. The worker then feels himself involved in the process, he no longer performs his work passively; he perceives the importance of his role, he is aware of the influence that his evaluations and his punctual expedients have within the process.

But where does the need really arise to completely overturn the mechanistic perspective of the Taylorism and Fordist systems? What is the key point that marks the definitive transition from top-down logic to bottom-up logic?

2.1. The birth of modern organizational models

In California, in the year 1951, the Treaty of San Francisco marks the end of the American occupation in Japan. Loaded by the political and monetary legacy imposed by the United States since the end of the Second World War, Japan becomes an independent state and gives way to 20 years of strong economic growth during which it manages to establish itself as the third economic power in the world, after the United States and the Soviet Union.

Americans open their markets to Japanese exports, without imagining that Japanese products would soon become dangerous competitors of their own artefacts. So, in 1973 the serious oil crisis becomes a blow to Japan, which suddenly sees its rate of growth go from a 10% annual growth rate (with peaks of 14%) to 5-6%.

The rationalist spirit of the Japanese people who, even with low wages, can save money, has allowed the banks to always have considerable resources for credit. The awareness that the incautious imitation of the American model of mass production can no longer function and the desire of the great managers to get involved in researching the way to raise the economy of their country, we can see the path downhill that has led Japan to compete for the title of the world's leading economic power of the twenty-first century.

In this scenario Taiichi Ohno, Sakichi and Kiichiro Toyoda elaborate the bases of what will be called "the Toyota miracle". A single law, a single purpose, impregnates the thoughts of the most important administrative personalities of the company: "To reach America in three years".

"Was it really true that an American could make ten times as much physical exertion? The thing seemed unbelievable: the Japanese obviously wasted something, and if we could eliminate those wastes, productivity would have definitely risen to the desired levels "(Ohno, 1988)

Load of expectations and spirit of enterprise, the Toyota Motor Company becomes the focal point of the Japanese revival and the cradle of the Toyota Production System. Until then the car company had been almost imperceptible in a market dominated by American giants.

"At the beginning of the eighties, with its 3 and a half million vehicles thrown onto the market - made with a number of employees almost 10 times lower than that of its most direct Western competitors - Toyota was firmly installed in second place in the ranking of world producers "(Revelli, 1993)

But what is the key to Ohno's success?

Ohno transfers the one best way philosophy adopted by Toyota to the entire production process.

Few, direct goals come into play. Eliminate walls ‘overloads’, walls ‘inconsistencies’ and muda ‘waste’.

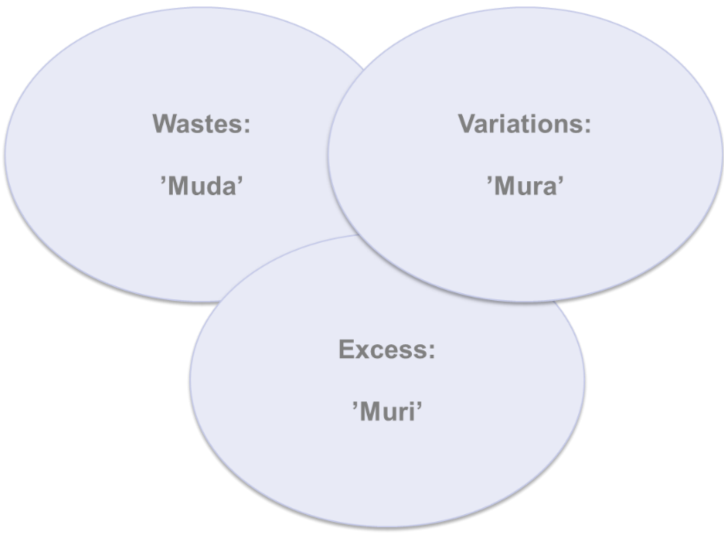


Figure 2.2 Onho’s theory

How? Through the implementation of the oriental principle of Kaizen, continuous improvement, using two important tools:

- "Just in time"
- "Self-activation"

Ohno acts directly on the production line, sensing the importance of bringing the worker and precise and timely production to the centre of the company's attention. The concept of an "integrated factory" is born when the operator must completely dissolve and free his/her own intelligence in the work process, carrying out his/her duties, planning, constantly supervising the production line, reporting errors in time. Real, limiting the risk of an accumulation of defective product and therefore unusable.

The constant successes of Toyota and all its satellite factories have brought Japan to the centre of global attention. In fact, America, after the post-war gold age, finds itself having to suffer the blows of a poor competitive capacity on the market and witnesses a drastic devaluation of the dollar. The Fordist policy adopted up to that moment, leads to an exorbitant accumulation of unsold material, which, like a black hole, begins to suck up the entire US economy. But Japan continues to grow, despite the hard blows suffered during the world war and the oil crisis. The focus on Japanese production models is increasingly pressing, each nation looks with admiration and emulation spirit Toyota and Ohno.

Figure 2.3 Kaizen

However, a correct production strategy is not a universally valid law and cannot disregard the social, political and economic context in which it operates.

The idea of lean production thus begins to spread throughout the world but above all they begin to glimpse all its most diverse facets. Each company takes and adopts the principles of the Toyota Production System, adapting them to its production reality, choosing to modify them according to the needs of the moment.

In this perspective fits the figure of Hajime Yamashina.

"An academic by profession in Japan, a samurai in the soul, but completely westernized in the ways and in the style, well known abroad and little loved at home" (From the Kyoto guru the secrets of the WCM, 2010)

He chooses to spend the rest of his life traveling, studying each country from a political, cultural, social and industrial point of view and trying to get the best organizational model for each visited establishment.

Seen in Japan almost as a heretic, he "dirty" the purity of the Toyota method, he molded it according to the needs of his clients. Become the Sensei of a new production model, son of the Kanban, but more flexible and at the same time specific: The WCM, World Class Manufacturing.

In 1986 Richard Schonberger collected dozens of cases, experiences and testimonies of companies that following the approach dictated by Yamashina, have embraced the logic of Lean Manufacturing.

He reunites all the concepts and experiences of TPS in a single organizational model: WCM, World Class Manufacturing.

Alongside the Kaizen philosophy there is a new pivotal point for the production system, namely Cost Deployment.

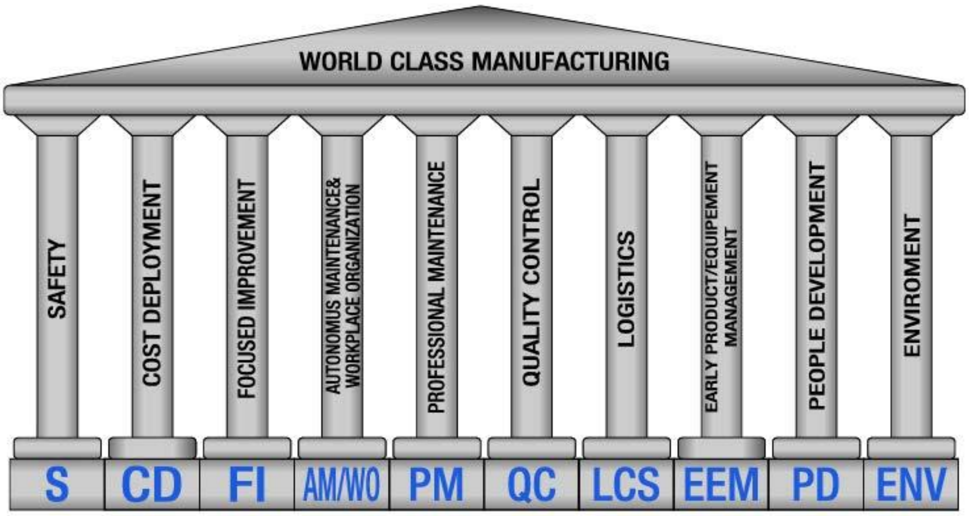


Figure 2.4 World Class Manufacturing

Yamashina introduces itself to the Western world describing the 10 basic rules, the so-called pillars, which constitute the temple of the WCM. They are:

1. Safety

The goal is to eliminate and monitor incidents in such a way as to make them as harmful as possible.

2. Cost Deployment

Identify problems from the point of view of costs, recognizing all sources of economic loss.

3. Focused Improvement

To know in depth how to reduce costs, focusing each time on a specific problem.

4. Autonomous Maintenance & Workplace Organization

Increase the level of training to allow workers directly engaged on the production line to monitor their work station, constantly managing the correct operation of the machines.

5. Professional Maintenance

Eliminate the sudden interruptions of the process through the intervention of a specialized maintenance team.

6. Quality Control

Reset defects through in-depth and constant monitoring at every stage.

7. Logistic & Customer Services

Fully satisfy consumers by promptly placing quality products on the market at the lowest possible cost.

8. Early Equipment Management & Early Product Management

Constantly use new products and innovative equipment that improves production.

9. People Development

Train and educate people to fully realize the WCM. Investing in people means focusing resources on a production method that makes man the key to obtaining maximum economic return.

10. Environment

To take care of the work environment, making it a livable and as welcoming as possible, tailor-made place for the men who will have to work within it and which naturally must be brought to the best.

From now on, most companies on the world market will adopt this method, reaping profits and chasing the constant aspiration of winning on the market.

James Womack, researcher at MIT, author of the text "The machine that changes the word", founder of the Lean Enterprise Institute, codified the Lean vocabulary explaining in a simple and direct way how to use the lean tools.

He does not agree to be called Lean Guru or Lean Manager claiming he "never managed anything". He spent his life asking questions without giving answers but expecting to receive them from his interlocutors, validating his first fundamental principle "no Walk, no Talk" (Womack & Jones, 1997). Walking and showing respect, he gathered within a single text the description of a practice that is indispensable for understanding and identifying every possible situation in a Plant or a company.

It underlines the importance of the word Gemba defined not as a factory but as "the place where value is created", considering the whole flow of value and not just the individual workstations. Walking along the production line is the only way to get to know the root of losses or non-compliance, starting the transformation of the Plant, solving problems, optimizing the flow of value.

There are ten questions to ask during a Gemba Walk:

Figure 2.5 Gemba Walk

The process is the fundamental unit of measure to create added value, defined as the succession of the right operations, made in the right way at the right time, with an adequate knowledge of the needs of the final customer.

2.2. Lean Management

Lean Production can be applied by every company in all the elements of the company.

The tools analyzed in Section 2.4 are indispensable for different internal points of view, both for internal teams and for external teams.

However, if they are adopted in a simplistic way, applying them in isolation to the need, the difficult but essential task of changing the whole organization and the way it can be managed is not completed.

Large companies increase efficiency and innovation, trying to follow four essential management disciplines:

• Offer value to the customer effectively

• Allow people to help continuous improvement

• Linking strategies, results and operational objectives

• Discover better ways to work...

These four disciplines do not represent strict rules for "good management".

However, when they are applied effectively and when they are consistently applied at every level of the organization, they reinforce each other to create a flexible organization that constantly generates the highest possible value.

"It is therefore essential that a figure guide, manage and monitor the entire process of horizontal creation of value," (Womack J., 2011) ".

This is the task of the Lean Manager who must deal with three fundamental elements:

1. Ensure that there is a manager of the Flow of Value that supervises and continually improves every part of the production process, satisfying both the client's needs and those of the company. The Value Stream Manager will need a team whose components are directly involved in the flow.

2. Involve Value Steam Managers to understand how the process would improve. It is essential that the focus is on processes and not on process numbers in order to avoid recognizing a problem immediately, not just at the end of the quarter or year when assessing quality at the end of the assembly line.

3. Teach managers to ask questions about their value flows and not give answers and orders. Applications can be turned into experiments using the scientific method of the PDCA - Plan Do Check Act. Using these scientific tools constantly tested to answer questions, produces significant improvements in the flow of value.

It is therefore essential to know the company objectives and the best management models to best use the lean tools by asking three simple questions:

1. Has the business objective of the process been correctly defined?
2. Are actions taken correctly to create value? Is the flow a pull at every stage of the process while eliminating waste?
3. Are all people in contact with the process actively committed to improving it?

2.3. Value Stream Mapping

2.3.1. The concept of value

Applying the principles of lean production means to look for waste and eliminate them in order to produce more with a lower consumption of resources (e.g., human labor, equipment, time, space), constantly orienting towards the needs of the customer.

The starting point for the search for waste is the identification of what has value for the consumer. Often when one thinks of the concept of value one falls into simple formulations such as achieving the lowest cost, offering a greater variety of product or high personalization and high levels of service, rather than rethinking what the activities really are relevant to the consumer.

1 - The value for the customer can therefore be defined as "The ability to satisfy the customer's needs at a given price and at a certain moment" (Rother & Shook, 1999), considering that the customer combines his perception of product quality and of service, with that of the price paid, obtaining what for him is the value.

Figure 2.6 Lean Customer Value Creation Process

Another reason why companies find it difficult to define the concept of value is that the creation of the same often happens through different companies (producers, suppliers), but each of these tends to define it in a different and independent way without considering the product, thus evaluating the perspective perceived by the customer.

The search for the true concept of value for a given product necessarily implies the redefinition of producer-client relationships and relationships between companies that are along the same flow of value.

At this point, once the value for a given product has been defined, an important objective is to determine a target cost based on the amount of resources and work for the realization of the same; this is determined in the hypothesis that all currently visible Muda are removed from the process.

Traditional companies set the selling price based on what they believe can withstand the market, then working backwards to establish the acceptable level of cost to ensure an adequate profit margin.

On the other hand, lean companies look at the price and characteristics offered to their customers by traditional companies and ask themselves how many costs could be avoided by applying lean methodologies. The value thus determined becomes the target cost for product development, order management and production activities required for that product.

Since the target cost will certainly be below the costs that the competitors have to bear, the lean company can choose between several alternatives:

- Reduce prices (in order to increase sales volume)
- Add features or potential to the product
- Use the profits thus obtained to encourage the development of new products.

2.3.2. Value stream mapping

The flow of value is made up of a set of actions necessary to face the three critical phases of the management of any business: the resolution of problems, the management of information - from receipt of order to delivery - and the physical transformation of raw materials into a finished product. (Rother & Shook, 1999)

The mapping of the flow of value is done by analyzing the set of activities that, starting from the raw material leads to the creation of the finished product, analyzing the flow of information and materials, identifying what has value for the end customer.

This systematic process highlights the existence of three types of activities:

1. Valuable assets that directly increase the value of the product as perceived by the customer.

2. Activities that do not create value but that are necessary or activities necessary to create a product but that do not have value for the customer.

3. Wastes or activities that do not create value and can be eliminated.

Using paper and pen, the Value Stream Manager draws the current flow of materials and information, identifying and cataloging the pockets of inefficiency.

Once the Current-State Map has been identified, the Future-State Map is drawn, identifying specific objectives and the expected results:

- Show exactly what you plan to do and by when, step by step
- Define measurable objectives
- Define checkpoints with real deadlines and auditors established in advance

2.3.3. Flow

After defining the value for the different activities, reconstructing the flow for a given product and eliminating the activities that do not generate value, it is necessary to guarantee the flow without interruptions.

The principle behind mass production is that the best way to achieve system efficiency is to group similar activities together and process them in batches.

This type of approach is often defined for Batch and Queue. It has the advantage of full-time operators and full-time use of the equipment.

Ohno has subsequently demonstrated how it is possible to guarantee a better overall functioning if the attention is focused on the product and its needs rather than on the company and on the plants, so that all the activities required to design, order and supply a product take place in a constant, stable and continuous flow. Is essential:

- Focus on the real object and never lose sight of it, from the beginning to the end of the process

- Break the traditional boundaries of tasks, professionalism and functions to create a lean enterprise, which removes all obstacles to the generation of continuous flow for a given product (or product family)
- Rethinking practices and equipment related to specific work to eliminate inefficient flows, waste and stops.

Value creation starts from the design phase. It is essential to eliminate imperfect communication between the different company functions, avoiding the flow of information and materials that go backwards along the process due to rework or redesign of the product at a point downstream of the line to resolve the incompatibilities between the needs of the various specialists involved.

The lean approach involves the creation of dedicated product teams, equipped with all the skills necessary to recognize value-added activities, understand the general project, engineer it, manage procurement.

In the lean enterprise, sales and production planning are essential components of the product team, able to plan sales campaigns as soon as the project has been completed, to sell having a clear understanding of the capacity of the production system and eliminating the need for reminder activity.

The key to implementing this approach is the takt time concept which defines the pace that production must have to meet customer demand.

The volume of orders can obviously increase or decrease and the takt time must consequently be modified in such a way that the production is always synchronized with the demand, avoiding bottlenecks.

The product teams must therefore acquire transversal skills in each task and the plants must be made 100% available through the application of a series of techniques known as Total Productive Maintenance.

This also means that the work must be rigorously standardized, and that workers and machines must be able to monitor their work through a series of methodologies called poka yoke, or fail-safe, which prevent even one faulty part from being sent. to the next phase. The jidoka and Andon connected to it are linked to visual checks or status indicators.

2.4. Lean Tools

Manufacturing companies have used lean management principles to eliminate waste, streamline processes and reduce costs.

This pragmatic approach is used to achieve a structured solution to problems and can be applied to improvement projects in companies that produce any type of product, from Consumer Goods, Automotive, Industrial Equipment, Life Science and Fashion.

It is a step-by-step approach to analyze processes and identify problems and opportunities for improvement, mapping the flow of value. Leaders can help a team to identify problems, their root, to consider additional problems related to methods, materials, labor, machinery, and the environment, using a cause-effect diagram.

The team is then able to organize the problems identified in logical groups and prioritize groups for impact and difficulty. Leaders must carefully manage the tools, trying to instill a sense of responsibility in those who have the task of completing the work. (Naples & Tonchia, 2009).

2.4.1. Jidoka – Autonomy

Jidoka in Japanese is the product of the term’s automation and autonomy and introduces the term "autonomy". Describes the required union between machine and man.

In fact, on one side the plant or the machine must be able to stop when the quality of the product is no longer guaranteed; on the other hand, the man, guarantor of the result, can intervene directly on the line avoiding the initiation of anomalous processes and implementing small measures essential to obtain an optimal functioning of his position.

The principle of Jidoka can be summarized in four basic steps:

1. Discover an anomaly

2. Stop the production

3. Solve the problem immediately

4. Investigate and correct the root of the problem

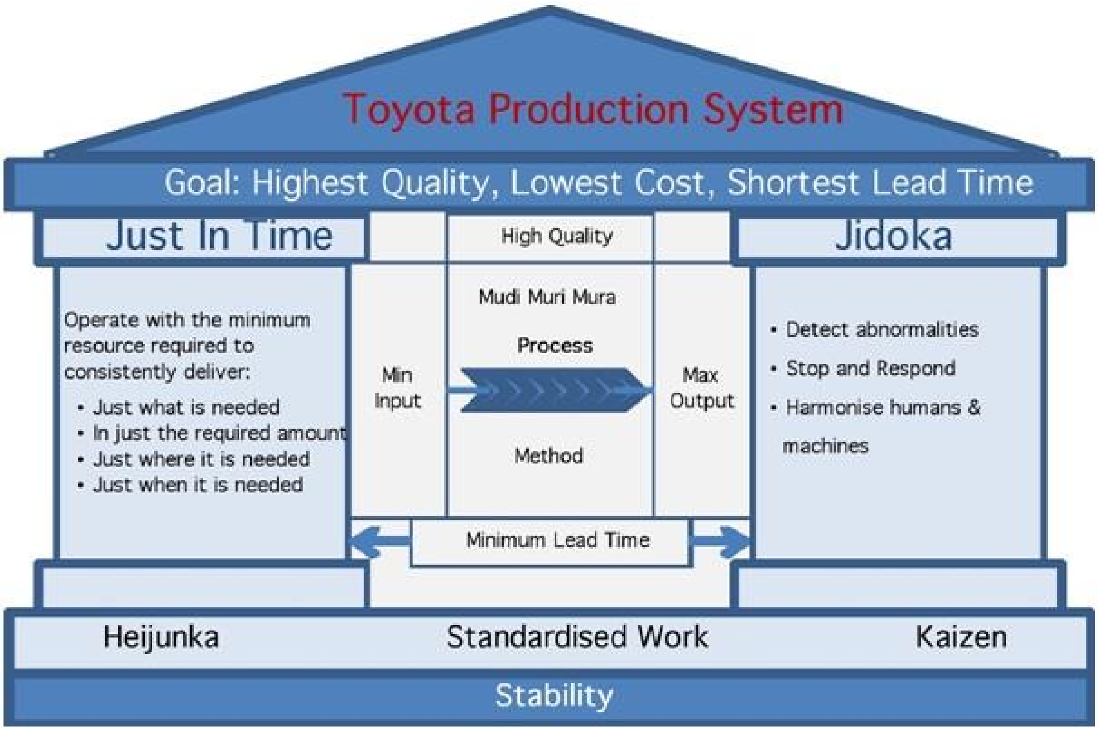


Figure 2.7 Toyota Production System

Each operator has the right to stop the process when he discovers an anomaly in order to highlight the defects and make decisions that solve the problem at the origin.

These conditions can be guaranteed if "intelligent" machines are introduced into the production system. This result is achieved by an active intervention by the operator, who is placed at the centre of the process, as the guarantor of the result, and invested with great operational responsibilities.

In fact, man:

- It is authorized to stop the line and avoid the proliferation of anomalies, in case you notice a defect.
- Is involved in problem solving through the development and construction of Poka Yoke, simple measures that allow the operator to verify the correctness of the operation that is going to be accomplish or that has just ended. These are control blocks, preformed containers on the shapes of the components to be transported.
- It is incentivized and used to wondering why an event, discovering the root cause of a problem, in order to eliminate it completely.

In this way it is possible to realize the final goal of the Jidoka, that is the unlocking of the rigid man-machine bond and the transition from an automation concept to an autonomous one.

The operation of this system is guaranteed in different ways:

- Building a culture that allows operators to solve problems in real time
- Position visible standard samples in such a way as to constantly compare them with the models produced
- Equip the machines with features of relief devices and automatic stop
- Provide survey systems and statistical analysis that reveal the possible drift towards non-compliance

2.4.2. Push VS Pull

The term "Push" means pushing, i.e. managing processes in advance of customer needs and is a typical feature of Fordism.

During the period of economic growth the Fordist manufacturing system dominates the organizational models of the world industry. In this period of strong productivity, the only goal is the reduction of costs through the creation of an increasing number of products with equal resources involved. The production line moves at a constant speed and marries the logic of "the more I produce, the more I sell". There is therefore a strong compression of the active intelligence of the operator who always performs the same movements by operating on high quantities of goods subsequently accumulated in the warehouses.

Push management is characterized by an anticipation of the entry of materials in the factory in order to guarantee the delivery time required by the market; this is done by using forecasts: if these are incorrect, inventories are generated whose effect is to lengthen the production time (P) instead of shortening the delivery time (D = Delivery); the progress is regulated not on downstream needs but on the basis of forecasts of these needs and a consequent plan to synchronize the departments in cascade.

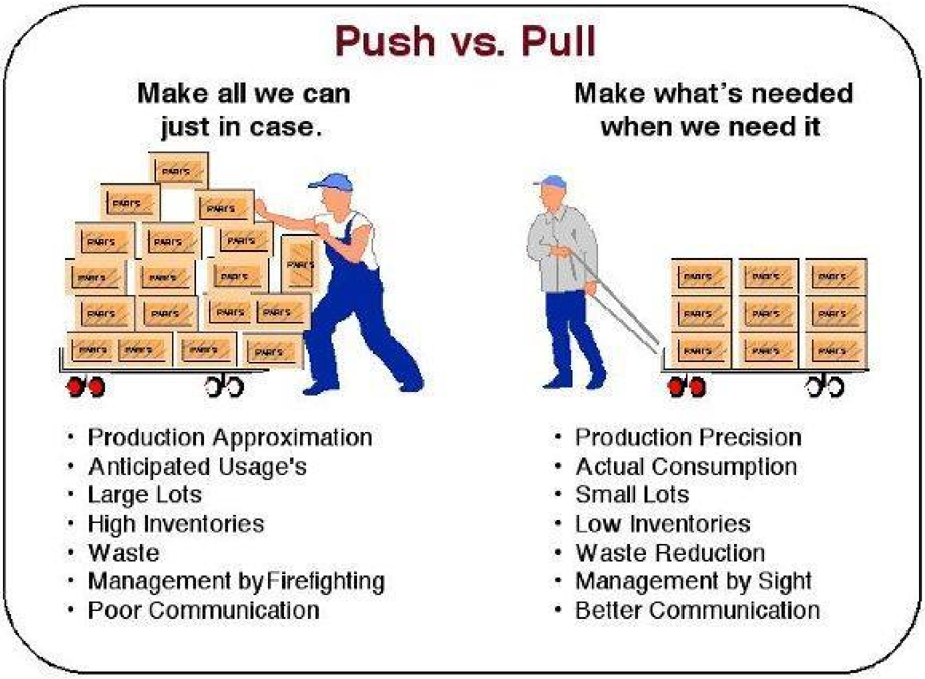


Figure 2.8 Pull vs Push

This system, solid in a period of great economic boom, collapses under the weight of the oil crisis of the '70s, as it is unable to cope with the demands of a variable market.

With the Toyota Production System, we are soon witnessing a complete overturning of the perspective of the great American industries. The production cycle starts now from the customer, is modeled adapting to its needs. The guarantor of the correct functioning of the line is the worker who actively participates in the process.

The idea of the "integrated factory" was born, understood as

"A unified and homologated factory community, in which the worker must consciously and voluntarily" dissolve "his / her intelligence in the work process, combining executive functions with control and design performance, reporting defects in real time and participating directly in the redefinition of the structure of the working process itself in relation to variations in demand "(Revelli, 1993).

The "Pull" logic is introduced, characterized by information that travels from the valley to the top. It is the customer who dictates their own times and conditions, moving the progress of the production line that advances using a lower amount of material and simple and direct information.

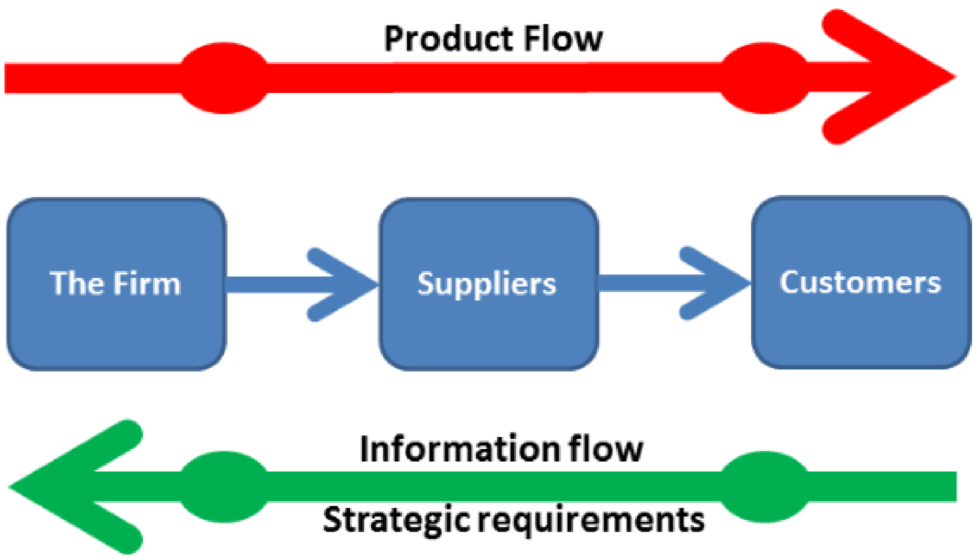


Figure 2.9 Product vs Information Flow

Analytically, the transition from pull production to push production is defined by the time of production and delivery.

P, the total production time is defined as the cumulative crossing time of a product, from the moment the raw materials are sorted to that in which they are transformed into a finished product, passing through the various phases of the process.

Time P is the minimum time horizon which production must look to the final market by determining the length of the production program.

In addition to P, it is necessary to calculate the time D, or delivery time, in the company, that is the time interval between the moment when the customer orders a product and the moment in which he wants this product to be delivered to him. Its value is generally fixed by the customer or the market and is therefore a data that cannot be modified by production.

If P>D the production program extends over a time horizon equal to P and we are able to fill production orders only up to the instant D; the remaining P – D range must be managed by forecasts.

In the second case, P<D, the production program is already completely defined by orders that even extend beyond its time horizon.

In the D-P interval we have a certain freedom in the management of order fulfillment priorities, which we can use to optimize production phases.

A P/D ratio greater than 1 implies the need for a capital investment at the moment P with an expected return at the time D (at which time the risk phase ends).

This situation is similar to a customary financial investment decision, such as the purchase of shares or bonds.

The question that arises is: will we obtain an adequate return on investment, considering all the risks connected to the unreliability of forecasts, to obsolescence and to deterioration?

The risk is greater the larger the P-D interval and therefore the importance of minimizing it is understood.

Lean Manufacturing System privileges this type of approach.

A production system is defined:

- PUSH if P/D >1
- PULL if P/D <=1

A pull system is governed entirely by orders and therefore does not seem to require forecasts.

This is actually true only for products, but it is necessary to plan plants and workforce, i.e. resources that define the productive capacity of a process. These must also be supplied with sufficient advance to be made available at the time of use.

2.4.3. JIT - Just in Time

Just in time is the principle according to which the production line manages to move parallel to the business, perfectly modeling itself to the demand. To obtain a correct coordination between the parts, it is necessary to use three tools:

1. "Pull" Logic: the information travels from the valley upstream. It is the customer who dictates their own times and conditions, moving the progress of the production line that advances using a lower amount of material and simple and direct information.
2. "One-piece flow": each product moves along the process one unit at a time without sudden interruptions, in the quantity determined by the customer. All this is achieved by subdividing the materials into small batches, ensuring frequent shipments, bringing the materials as close as possible.

3. "Takt Time": it is the measure of time in minutes and seconds necessary to produce a piece or a product. It is calculated from the number of pieces to be produced and is obtained through the formula

$$Tt = \frac{\text{available daily time}}{\text{number of pieces requested per day}}$$

Schonberger, pioneer of the JIT application in the USA, defines it as a System to produce and deliver finished products just in time to sell them, assemble in assemblies just in time to mount them on finished products, and buy raw materials just in time to transform them into components.

It is a set of techniques aimed at simplifying and rationalizing the productive system of a predominantly organizational-managerial nature. It intervenes along the entire value chain, prioritizing the flow, seeking continuity and regularity.

The JIT pursues the objective of the dynamic stability of the production system, aiming to shorten the response times of the production system, harmonizing the variability of the market and the need for stability in production processes.

2.4.4. Cellular Manufacturing

In a manufacturing cell, all the operations that are necessary to produce a component or a sub-assembly, are brought to term in the immediate vicinity of the working station, in order to obtain immediate responses from the various operations to problems. Operators are generally cross trained and able to perform multiple tasks when necessary.

Increase coordination and improve communication.

The Figure 2.10 underlines the different shapes which a production line can have. The arrangement of the U or C cells, allows the procurement of materials from the outside in a critical area of entry or exit of the flow in an easy way for the unloading. These are possible comfortable dispositions which the machine might have in the plant.

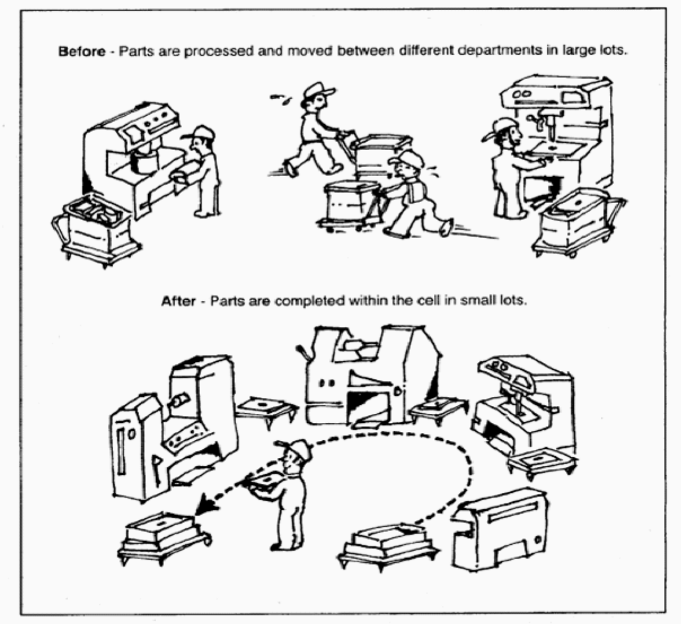


Figure 2.10 Line Optimization

The operators that deal with the transport of raw materials or semi-finished products, thanks to this type of layout can make a Milk Run easier by first supplying and then emptying the stations.

Essential for the design of the cell is an excellent knowledge of the process in terms of the number of employees in the cell, number of workstations, batch size, takt time, scheduling, supervision and communication.

2.4.5. Kanban

The main means through which the entire Toyota production philosophy is built is the Kanban, the tag. It is an information system used to control the number of parts to be produced in each process.

"In the most common and frequent form in our companies, it consists of a piece of paper contained in a rectangular vinyl wrapper." (Ohno, 1988)

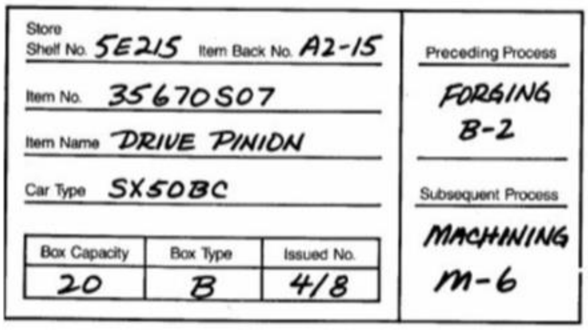


Figure 2.11 Example of Kanban

It contains a series of information about the fundamental characteristics of the article, the quantity to be produced, the operations to be carried out.

The Kanban is the soul of the Toyota system, the character that reveals the reversal of perspective with respect to the Fordist system. These are the final extremes of the production process that start the information that goes back along the entire production line up to the central programmers. Kanban cards follow the flow and return once the container has been used.

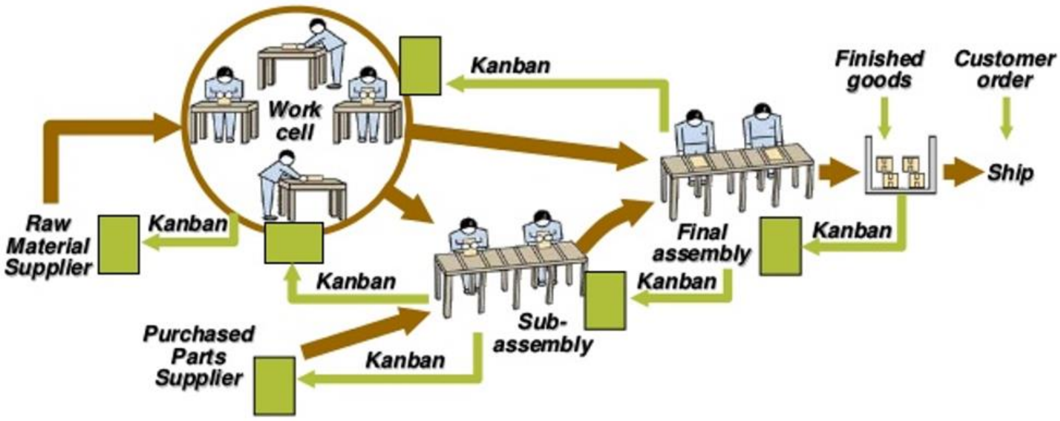


Figure 2.12 Kanban flow

The process is transparent and timely. The small fluctuations in the demand are automatically and autonomously managed by each workstation without requiring the intervention of the supervisors and instantly limiting any anomaly.

2.4.6. OEE - Overall Equipment Effectiveness

The OEE, Overall Equipment Effectiveness, identifies the percentage of planned production that is actually productive.

The main elements necessary to apply the OEE are

- Availability, defining losses due to inactivity (e.g., failures, set-up times)
- Quality, calculating losses due to defects (e.g., waste and rework, startup time)
- Performance, i.e. loss of speed (e.g., arrests due to small inconveniences, reduced processing speed)

The OEE is calculated as follows

$$OEE = \text{Availability} \cdot P\text{productivity} \cdot Q\text{uoily} = B/A \cdot D/C \cdot F/E \cdot 100$$

In which

- A is the net operating time
- B is the operating time
- C is the production goal
- D is the real production time
- E is real production
- F is compliant production

The OEE can be alternatively defined as the ratio between real production capacity and ideal production capacity expressed in percentage terms.

The score obtained, identifies the production performance

- If the OEE is 100%, you have perfect production

- If you have 95%> OEE> 85% you have excellent productivity
- If you have 85%> OEE> 75% the production is mediocre
- If you have 75%> OEE> 65%, you have a low production rating

By collecting the OEE data on a fixed basis, it is possible to identify the procedures and the interferences that cause problems to the productive equipment. Moreover, the collected data allow to evaluate if the interventions implemented to improve the performance of the machines have given positive results.

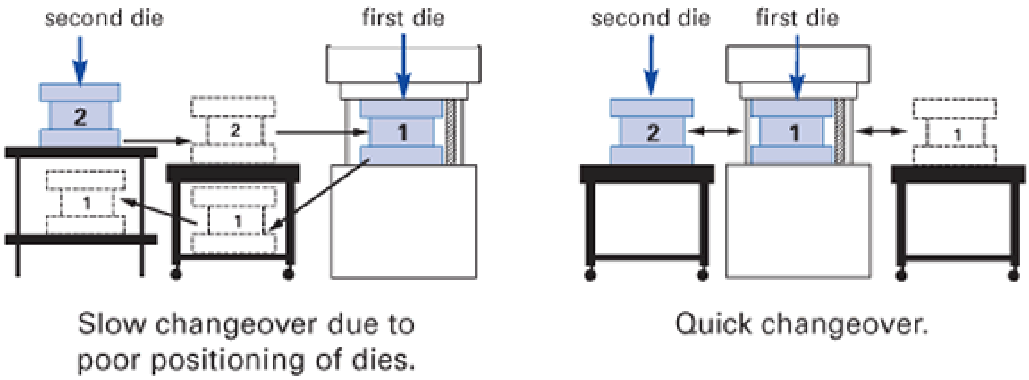
By marking the data over time, you will be able to see the progress of the OEE for the machines and answer other questions like:

- What are the main problems of inactivity?
- When did that accident happen?
- How was quality last month?
- How are we using the facility?

2.4.7. SMED - Single Minute Exchange of Die

In the 1950s, Shigeo Shingo, a Toyota industrial systems consultant, developed the concept of Single Minute Exchange of Die or substitution of equipment in minutes less than ten minutes.

Thanks to this tool, we satisfy the need to minimize internal set-up times (performed when the machine is stationary) and external of a machine, (carried out when it is in production), considerably reducing the size of the lot.



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The fundamental objective is the reduction of time to no added value, in order to guarantee the very high flexibility of processing small batches.

The goal of this methodology is ambitious, and not always possible to achieve, but despite this, the application of the suggested procedure and techniques can lead to surprising results.

The implementation of a SMED system goes through four implementation phases:

1. Analysis of the initial situation and identification of set-up times

2. Net separation of an internal and external set-up, highlighting the operations that can be done while keeping the machine running

3. Conversion of the internal set-up into an external set-up

4. Improvement and standardization of internal and external set-up procedures

There are numerous advantages deriving from the application of SMED and allow to overcome the typical problems of mass production.

- Increased flexibility: having a lower incidence of the setups on the processing cycle times, it will no longer be necessary to produce large batches to compensate for long tooling times, as the advantages of this production mode will no longer be tangible.

- Reduction of lead time and waiting time for the customer: with the traditional production method, delays and lengthening of the lead time are becoming more frequent as we try to anticipate the production of orders with equal pieces to reach certain batch sizes, but so doing so will delay the processing of orders received previously. The increase in flexibility offers the possibility to produce what you want when you want, reducing the time of crossing the line and consequently the delivery time to the customer.
- Increased product quality: using standard tooling procedures with precise set-ups from the beginning allows you to increase product quality
- Reduction of the warehouse and costs associated with it: the possibility of producing "on demand" at any time theoretically determines the possibility of eliminating the warehouses, with the costs associated with them, such as space occupied, cost of shelving, machinery for handling and reduces the labor for warehouse management. In reality, the total elimination of warehouses is very difficult to obtain if not impossible, but a large reduction in their size is still possible
- Reduction of the risk of obsolescence: all raw materials or semi-finished products kept in stock as stocks will have to be replaced in case a model change occurs. The parts replaced to make room for new ones can be sold at a lower price or thrown away: in both cases the company should incur considerable costs. Eliminating the warehouses eliminates the risk of keeping parts that can no longer be used in the future.

2.4.8. Takt Time

Takt Time indicates the rhythm of the productive pulsation, rigorously synchronized with the actual demand, by uniforming the rhythm of production to that of sales.

It derives from the German word Taktzeit, translatable as "clock time". Takt Time sets the rhythm of the lines of industrial production. In car production, for example, cars are assembled on a line, and are moved to the next station after a certain time - Takt Time.

The Takt Time calculation is performed through the following steps:

- Definition of the calculation time horizon
- Determination of the sales volume expected in the week
- Identification of available working time

With this data it is possible to calculate the Takt Time as

$$Tt = \frac{\text{Work time available}}{Forecast\ of\ volume\ of\ sales}$$

It is used to measure the number of workers inside the cell, considering also the Total Manual Cycle Time or the manual working time necessary to complete the analyzed process.

$$\#\ operators = \frac{\text{Manual cicle time}}{Takt\ Time}$$

After evaluating these two parameters, the necessary results are verified to guarantee the stability of the process and the achievements performed through standardization.

In the case where there is a chain of processes in which the Takt Time of an upstream process cannot be congruent with the downstream process, a decoupling will be necessary to absorb the differences in speed. They constitute buffers that represent "waste" par excellence but that must be maintained until the flow is synchronized.

2.4.9. Heijunka

Heijunka is the production leveling that balances the workload within the production cell while minimizing supply fluctuations.

This tool ensures that the outputs that follow each other in a line, variable in type and quantity, respect the satisfaction of customer demand to the utmost.

The main elements of Heijunka production are:

1. Leveling of production volume which depends on the uniform distribution of production over a given period of time

2. Leveling of the production mix depends on the variety of level production or the uniform distribution of the production mix/variety over a given period of time

"This system has made it possible to reduce prices during market-tired phases so as to keep production volumes constant". (Womack J.P., 1990)

In this way the customer demand can be better faced, the flow towards the Supply Chain is regular and there is an adequate sizing of the Supermarket for the customer.

Keeping the pace of production steady, it also ensures a constant turnover for suppliers. The latter can therefore use employees and machines more efficiently, without sudden changes in the volume and mix of orders with short notice periods.

An indispensable tool for leveling production is the "Leveling register" or the Heijunka Box in which the Kanban are distributed. It is therefore a table whose rows are the production lines and the columns the constant time intervals. The presence of the Kanban in the different stations specifies the sequences according to which the activities must be carried out.

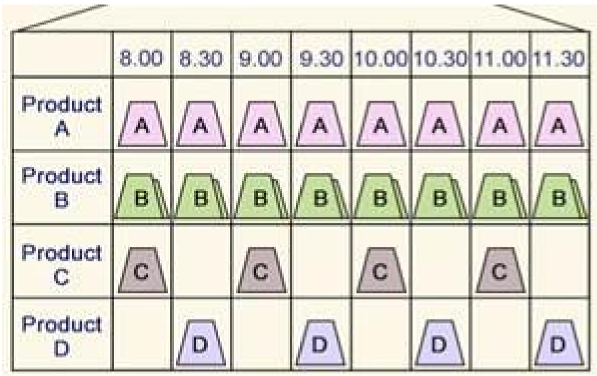

Figure 2.14 Example of Heijunka

2.4.10. TPM - Total Productive Maintenance

Machine breakdowns are some important problems that affect the production line. The term TPM -Total Productive Maintenace- indicates the whole set of practices, techniques and processes aimed at managing the entire production system.

Applying the TPM methodology is possible

- Making the use of plants and equipment more efficient
- Introduce a preventive and predictive maintenance based on statistical data
- Involve management and operators within the TPM programs
- Promote and improve maintenance activities based on specific autonomous teams

The current definition of the TPM was introduced in 1989 by the Japan Institute of Plant Maintenance and is based on eight pillars:

1. Autonomous maintenance of the operators, trained and trained to keep the plants efficient, inspecting the systems to identify and correct any anomalies

2. Maintenance Planned by specialized operators who are dedicated to prevention, fault analysis and the definition of intervention program standards

3. Training for operators and maintenance personnel on subjects essential for the operations to be carried out on the line

4. Preventive Management referred to the initial phase of the product life cycle which must be designed in such a way as to be easily realized and maintained

5. Quality constantly monitored thanks to the analysis of defects, countermeasures necessary to eliminate them and regulation of standards

6. Adoption by the "office" staff of the same techniques used on the line (e.g., standardization, 5S)

7. Improvement focused in such a way as to keep the optimal process conditions constant and maintain adequate maintenance standards

8. Safety and Environment in such a way as to control the conditions for event control, accident prevention, increased comfort of the Working Station

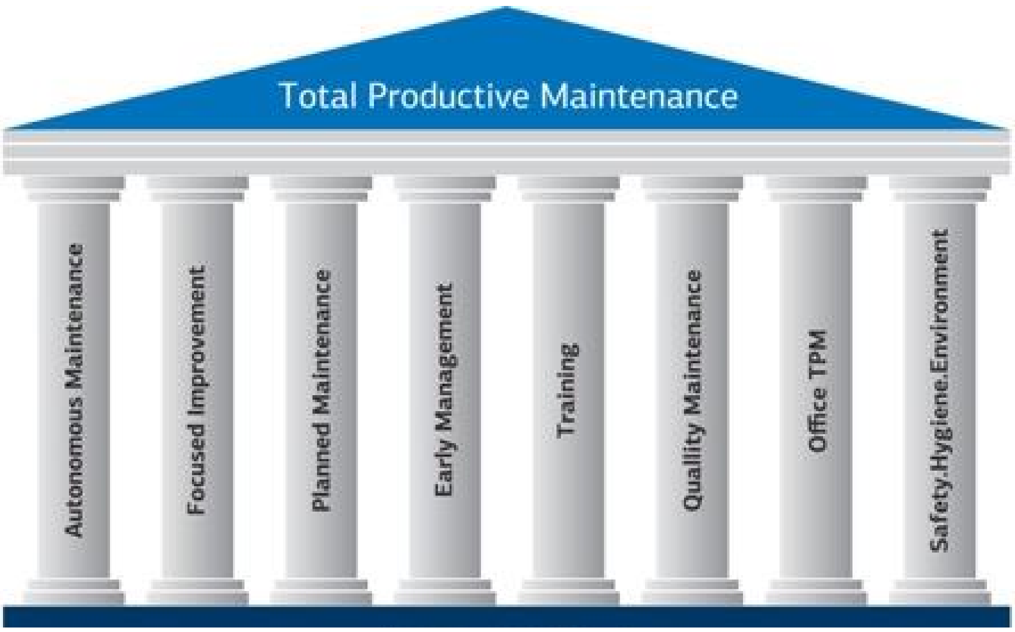

Figure 2.15 Total Productive Maintenance

Therefore, the work must be rigorously standardized thanks to devices that monitor the work of operators and maintainers as poka yoke devices, or fail-safe, which prevent even one defective part from being sent to the next stage. Concept connected to it are the jidoka and the Andon. These techniques must be accompanied by visual controls, 5S, status indicators, displays showing measurable key information. The techniques vary according to the applications but does not change the basic principle: anyone involved in the process must be able to see and must be able to understand every aspect of the operational activities and their state, moment by moment.

2.4.11. 5S

5S is a simple procedure for order management and cleaning of workstations. The 5S refer to five Japanese terms that represent the main steps of the methodology:

- Seiri (Sort) - Choose and Separate. Eliminate anything that is not needed in the workstation
- Seiton (Set in Order) - Arrange and organize. Efficiently arrange tools, equipment and materials.
- Seison (Shine) - Check the order and cleaning of the workplace;
- Seiketsu (Standardize) - Standardize and improve. Keep order and cleanliness created, try to improve by repeating stages continuously: Seiri, Seiton, Seison;
- Shitsuke (Sustain) - Support over time. Establish discipline and rigor for the continuation.

Figure 2.16 5s representation

1.Sort	➢ Work area identification ➢ Separation criteria definition ➢ Physical division of useful to useless material	• Red card to identify useless material • Stratification sheet to classify useless materials
2.Set in order	➢ Define the optimal amount of use ➢ code the objects ➢ Indicate the position of each object	• Colors • Visual signals • Codes • Maps
3.Shine	➢ Define the optimal operating conditions ➢ Clean and inspect the machines	• *Check list* of cleaning activities • Summary pages of the cleaning performed

	➢ Define operational and maintenance procedures	
4.Standardize	➢ Systematically distinguish useful materials from useless materials ➢ Make it difficult or impossible to put items in the wrong places ➢ Define completion rules and procedures	• Visual Management
5.Sustain	➢ Define the evaluation parameters ➢ Perform periodic check of the areas ➢ Identify any corrective measures	• *Visual Management* • *Check list*

Figure 2.17 Before and After 5s implementation

In every company the implementation of the 5S is the starting point that allows the improvement of production activities and future development. This is because, in the daily activities of a company, activities of choice and separation are usually carried out, as well as arrangement and organization and control, which are fundamental to obtain a linear and efficient flow of activities.

2.4.12. Poka-Yoke

Shigeo Shingo, analysing the aspects necessary to maintain a level of quality of the appropriate product, understood that to achieve the "Zero Defects" goal, the motivation and exhortation of the workers was not enough. Then introduced a series of devices that made the error impossible, automatically intercepting the anomaly. These devices are called Poka-Yoke, combining the words Poka, mistake of inattention, and Yokeru or avoid.

Initially they were mechanical devices dedicated to avoiding positioning errors to detect the lack of parts. Subsequently, their degree of sophistication is increased, allowing the blocking of the line to prevent a difference from arriving at the end of the process, immediately correcting the error and detecting the cause in order to avoid repetition.

The devices described in this paragraph can be based on different principles:

- The contact, detecting if an element is in contact or not with a device that acts as a sensor, highlighting the consent to continue the operation

- Achievement of the pre-established threshold value
- Detection of the pre-established movement to perform a function properly

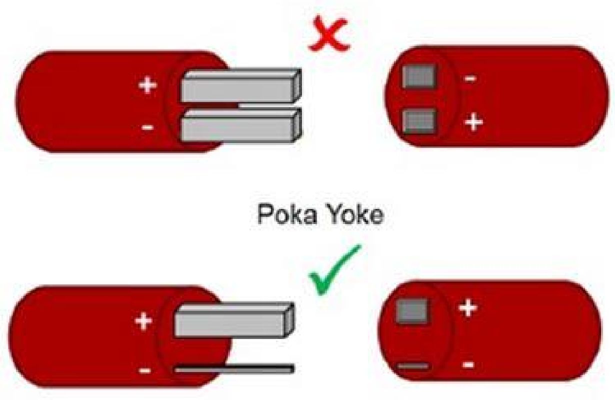

Figure 2.18 Poka Yoke Example

Product and process designers must design these systems early in the project, for example by analysing the product and the process. Today, with the possibility of using automatic signalling mechanisms, the Poka Yoke develops more and more through light signals (e.g., visual management, Andon) or sound signals, or line blocking and through the design of particular equipment for the cell.

2.5. Cost Deployment

The cost of implementation is an indispensable tool for estimating and managing costs and losses, eliminating them and identifying the root cause of the problem. Thanks to the cost of the distribution it is possible to identify the data in terms of cost. Losses and wastage are attributable to machines, materials or people and it is essential to understand the cause. The losses of an establishment are identified thanks to the OEE indicator are calculated considering the technical, managerial and quantitative efficiency.

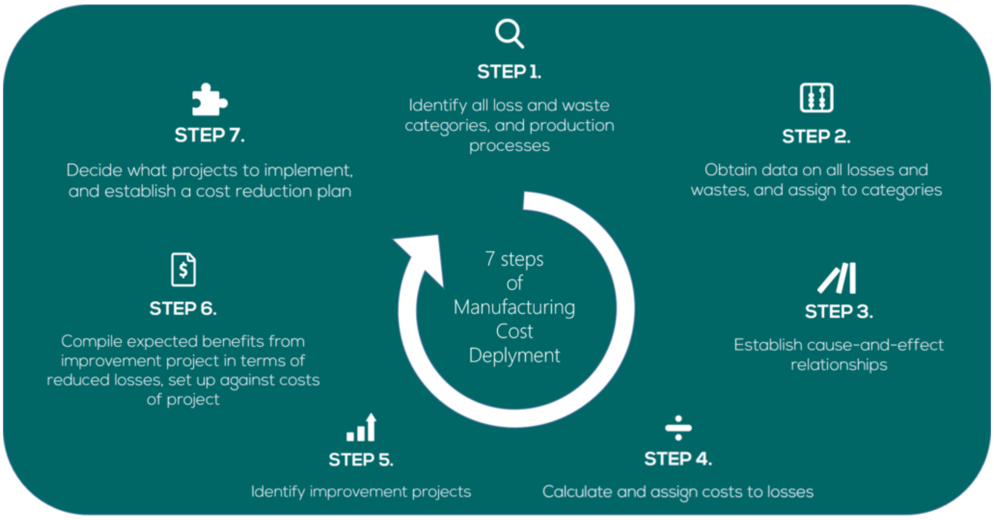

Figure 2.19 Manufacturing Cost Deployment

The key to the success of Cost Deployment is the precision in the measurements carried out, attributing to the costs of the losses that will then be transformed into profit. This process takes place through seven steps:

1. To quantify the total costs of the process and the transformation costs to define the priorities accordingly

2. Identify quality losses and waste

3. Separate "causal losses" from "derived losses"

4. Calculate costs resulting from waste and losses

5. Recover waste and losses in the production process

6. Define when costs decrease by eliminating waste and losses

7. Establish an implementation plan and repeat steps 4 to 7 for continuous improvement

2.6. Sustainability

It is essential to ensure continuity of initial results and sustainability for a multi-year lean program. It is therefore essential to avoid the initial enthusiasm becoming a general frustration for not achieving a common goal.

Using a metaphor, "We risk winning some battles but losing the war" against waste, where the program is not supported by a robust organization specifically designed, by a strong conviction and by the will at all levels, the engine of change.

The process that allows us to achieve the result of being Lean, or having a production system oriented towards the continuous elimination of waste (Muda) and whose application focuses on the Gemba, the physical place where we create the value for the customer (e.g., factory, department, line, technical office), is based on four pillars that allow the "flow pulled by the customer":

• Total Quality

• Total Productive Maintenance

• Just in Time

• Policy deployment: declining and "translating" business objectives at all levels so that every day the activities of all the people in the company go, consciously, in the same direction

Companies that successfully apply this process, progressively acquiring autonomy, develop their own Production and Management System. A lean production system cannot be achieved by copying application tools - like the Kanban - of other companies but must be realized by the people of the company by applying the principles directly to their own reality. Only in this way the improvement is sustainable over time and in line with the

"I feel and forget, I see and remember, I do, and I understand" approach.

2.7. The combination of Lean Production and Industry 4.0

The principles of Lean Production have been widely used in the manufacturing sector since the early 90s. The key features of the Snella production are the close integration between people and the production process, in order to guarantee continuous improvement and focus on value-added activities. In this way, productivity can be increased by 25% (Gröbner, 2007).

Today, we are faced with a new paradigm defined by the term "Industry 4.0", which in some ways may seem the revival of the Computer Integrated Manufacturing.

Guided by the modern ICT systems - Information and Communication Technologies - Industry 4.0 is a network in which components and machines are intelligent and are part of a network monitored by specific rules.

The fusion of these two industrial paradigms and their instruments accelerates the development of Industry 4.0, reducing the risks associated with the digital transformation project of existing manufacturing models. In fact, Lean processes, standard, transparent and focused on value-added operations, are less complex and facilitate the adoption of IIoT solutions that will be analysed in the following chapters.

The Department of Innovative Factory Systems of the Deutsches Forschungszentrum für Künstliche Intelligenz - German Research Centre for Artificial Intelligence - has identified four enabling factors for the creation of the Smart Plant: Smart Products participating in the production process and integrate with Smart Machines. Smart Planners that optimize the process in real time. Finally, the Smart Operators who, supported by the innovative ICT systems, supervise and control the activities in progress.

IIoT solutions can be seen as a way to support Lean Production by building standardized blocks to be used in the workstation to collect and structure data from sensors, actuators, PLCs and CPS (Cyber Physical Systems).

Chapter Three

Manufacturing transformation

Analysing the current industrial scenario, it is clearly identifiable a transformation of the workforce into a new horizon that is part of the fourth technological wave and consists in the advancement of new digital industrial technologies known by the term Industry 4.0.

Thanks to the introduction of these new technologies, the manufacturing industry is able to increase its competitiveness, using new production technologies, new materials, new ways of storing materials, processing and sharing data.

In this scenario, it will be possible to increase jobs, thanks to the increase in demand due to the growth of existing markets and the introduction of new products and services. This is in against trend compared to the previous technological era in which the number of jobs in industry has decreased despite the increase in production volumes allowing the introduction of automation.

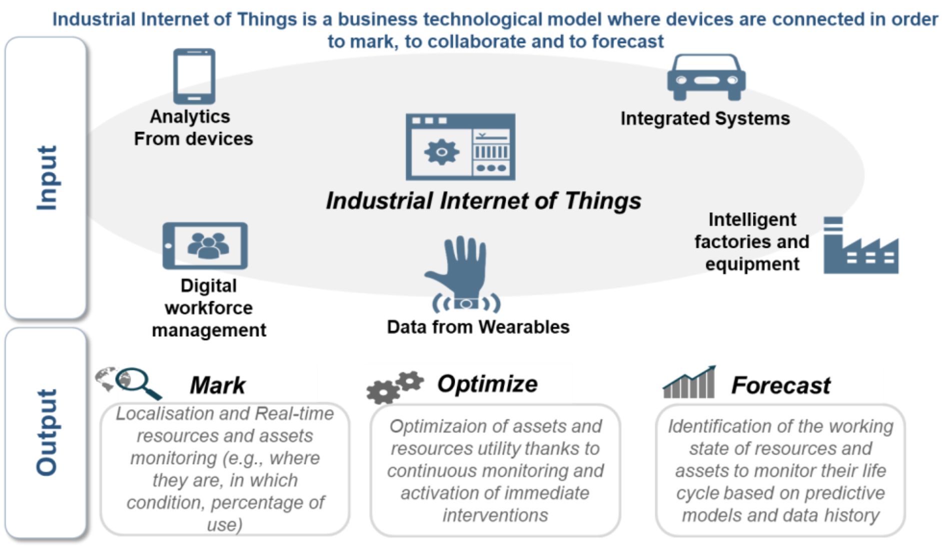

Figure 3.1 How Ilot can help the digitalization

3.1. The evolution of the industrial workforce

“According to a recent study by the Centre for European Economic Research (ZEW), digital transformation in Germany is creating more jobs than it is destroying.

“The Digitalization and the Future of Work” report notes that although more jobs are being created in the industry, the further implementation of digital technologies is changing employment structure.” (Global Manufacturing, Sophie Champan 2018).

The adoption of flexible production lines, autonomous robots or 3D printing, the implementation of innovative business models, the use of augmented reality, will lead to a significant increase in productivity, increasing cooperation between man and machines.

“Gartner estimates more than 8.4 billion "Things" are on the internet today, up more than 30% from just one year ago. However, IoT alone is just the start. It isn't so much about the things, but rather what we do with these things once they are connected and supplying us data. Three of the main trends I see — the analytics revolution, edge computing, and 5G cell processing — are all driven by the IoT at their core” Trends For Digital Transformation In 2018 - Forbes

Given the importance of data in Industry 4.0, business models show that the demand for industrial data management experts will have the highest growth along with IT and User Interface Designers. On the other hand, simple and repetitive work will be reduced because these activities can be carried out by the machines. While the introduction of robots will decrease the number of operators needed on the line, the introduction of tools for predictive maintenance or the augmented reality will allow manufacturers to implement new business models to promote job creation.

The paradigm shift involves industrial companies, education systems and governments. Entrepreneurs and politicians will have to try to ensure adequate levels of employment, increase productivity and market competitiveness.

“Establishments that invested heavily in modern digital technologies early on are still among the leaders in their industry, while those who came late to the party are noticeably falling behind. This divide needs to be tackled in a targeted way,” Arntz added.

“High-wage professions and sectors are the ones that are profiting the most from new technologies in the form of higher employment and wage increases, while low-paid jobs and sectors, on average, are losing out.”

It will be necessary:

- Reassign their employees to strengthen their workforce and keep pace with the technological innovations introduced.
- Effective training programs will have to be studied to train specific skills, by prevent- ting on-the-job training using advanced tools such as augmented reality. The skills on which training will be required will then be diversified to ensure the versatility of the operator by adopting new models of Work and Organization to ensure efficient man-machine integration, encouraging the introduction of working time flexibility also for Gemba workers. Furthermore, companies will benefit from horizontal organizational structures in order to manage the use and control of data on site, integrating reputed IT and operators.
- Recruiting the right people for Industry 4.0, focusing on the right skills for specific roles rather than grading and role-based qualifications.
- Engaging in Strategic Workforce Planning starting with gathering basic information about all employees, classifying the various types of workers into working families. The output of the analysis of supply and demand models can then be used to produce a broad analysis on the measures necessary to achieve continuous improvement

(e.g., personnel development, transfers, insourcing or outsourcing, adoption of new recruiting objectives).

3.2. Industrial Internet of Things: Economic advantages

“There is a shift from the focus on the number and diversity of connected devices towards a broader vision in which business goals, people and value take centre stage. This shift goes hand in hand with an equally broader vision of IoT as a combination of connected devices, connectivity, software, platforms, partners, data and apps in function of these goals.” (IoT 2018 – the next stage: the IoT of integration, value and action).

In Manufacturing, IIoT technologies can improve operational efficiency in a variety of ways.

The sensors can:

- Be used to monitor machinery and allow real-time updates on equipment status, decreasing downtime
- Being positioned on transport vehicles and pallets to improve supply chain management and monitoring
- Be used to monitor the flow of inventories in each area of the factory or between different workstations, reducing inventory levels, waiting topics, optimizing flows.

The McKinsey Global Institute estimates an increase in productivity between 2.5% and 5% by applying IoT in manufacturing industries.

In terms of operating costs, these are now around $25 trillion a year and could reach $47 trillion by 2025.

The main factors fuelling the growth of IIoT are:

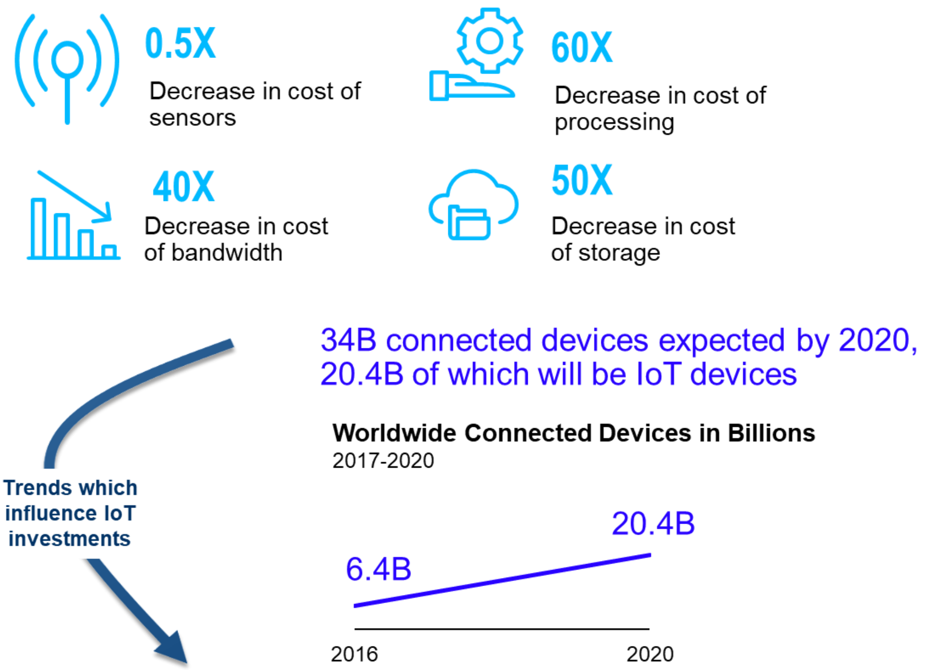

Figure 3. 2 Source: The Economist, Cisco, 3rd Party Research Firms, Ericsson, Programmable web, GSMA

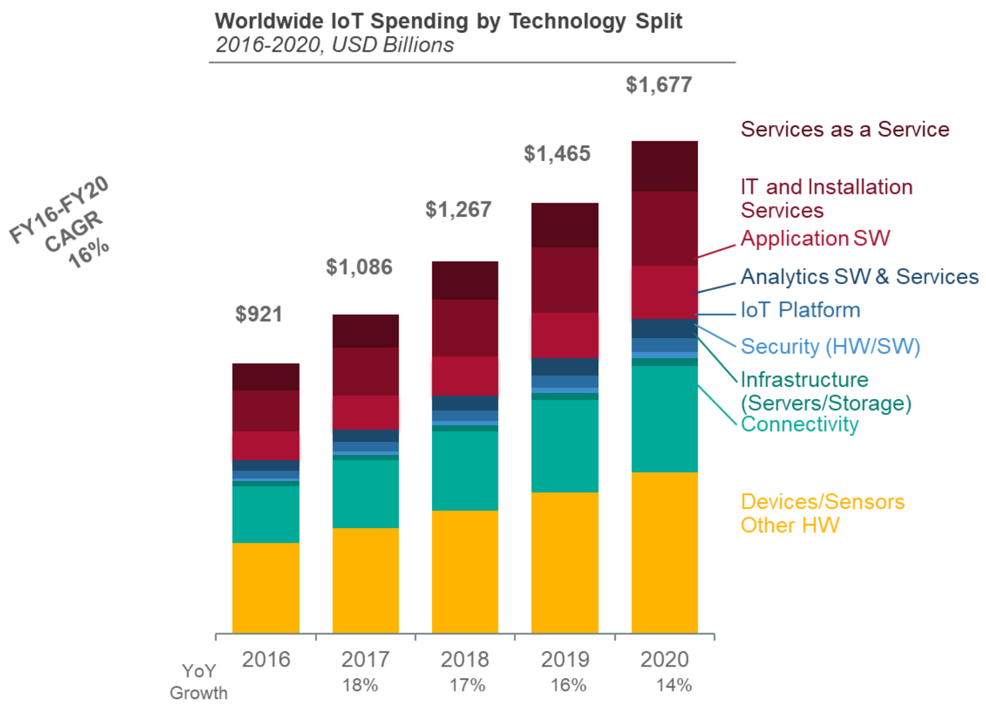

Figure 3. 3 Source: IDC

Accenture has recently published the results of a survey proposed to more than 1400 global business leaders; "84% of them say they can create new income streams from the IIT. 73% of them have not yet taken concrete actions in their plant to do so and only 7% have developed global strategies supported by targeted strategies "

- There is a gap between perceived readiness IoT readiness and reality

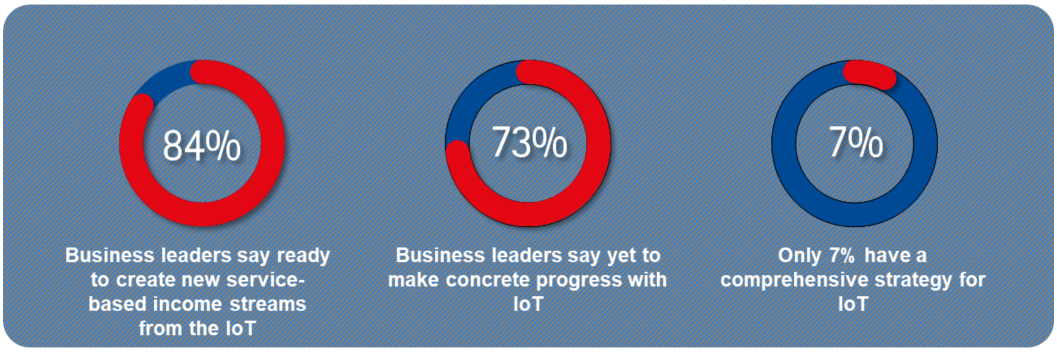

Figure 3. 4 Source: Accenture survey "From productivity to outcomes: using the internet of things to drive future business Strategy ", 2018

Smart factories distributed on a large scale, autonomously organized, highly automated and demand driven are implemented in a few cases and circumscribed cases. However, some companies have started to lay a solid foundation for building a Smart Production by adopting sensory machinery control mechanisms on the shop floor (e.g., production connectivity with management, manufacturing execution, logistics planning). The most significant result is the constant visibility on the machinery of the production process, applying advanced analytics to the data generated by their systems, easily identifying bottlenecks and developing a predictive process on the performance trend of the machines.

3.3. Connected Machines

The new technologies guarantee the visibility on the data coming from the machines guaranteeing a constant monitoring of the plant performance indicators in order to understand how each function works, to increase workers' safety and to collect data to obtain a "usage-based design".

Furthermore, the use of the IIoT has the potential to change relations between producers, distributors, consumers and financiers.

Production in particular, will have the potential to improve not only the performance of individual plants but also to ensure better visibility on the performance of production facilities located at important geographical distances. At the same time, the flexibility guaranteed by this new type of work will ensure greater compatibility between work and personal obligations.

Industry 4.0 operators will increasingly be at the centre of fundamental training and qualification processes for companies to ensure high rates of innovation.

Another important IoT application in the factory is Predictive Maintenance and warehouse optimization.

Predictive Maintenance is used to monitor Assets through sensors to avoid breakdowns and to establish when maintenance is required or to schedule routine maintenance. In order to start this kind of innovation it is necessary to renew or upgrade the Assets, also improving the connectivity and the machine-to-machine communication. Further upgrades are also necessary in the indispensable Data Analytics to collect and analyse data in real time, sensors, micro-electro-mechanical systems (MEMs), Cloud systems for data storage so that they are available in any place and in real time.

At the base of everything it is necessary to ensure data security and privacy, thus ensuring the confidentiality and integrity of company data, so that they are protected from unauthorized access.

The ability to connect and manage all the resources on the shop floor has a clear impact on manufacturing, not only to ensure visibility on the information obtained but also to improve the flow of the process and ensure a higher quality of the product.

Each component on the modern shop floor can connect to the IP address of the factory, producing real-time data and instructions that, managed in a

Cloud platform, guarantee efficiency, better use of assets and lower energy consumption. The workstation connectivity, monitoring materials and operators, favours the improvement of quality and traceability.

There is the develops of digital solutions and sensors utilizing advanced communications and control abilities to enable real-time, autonomous, self-directed, decisions by production machines.

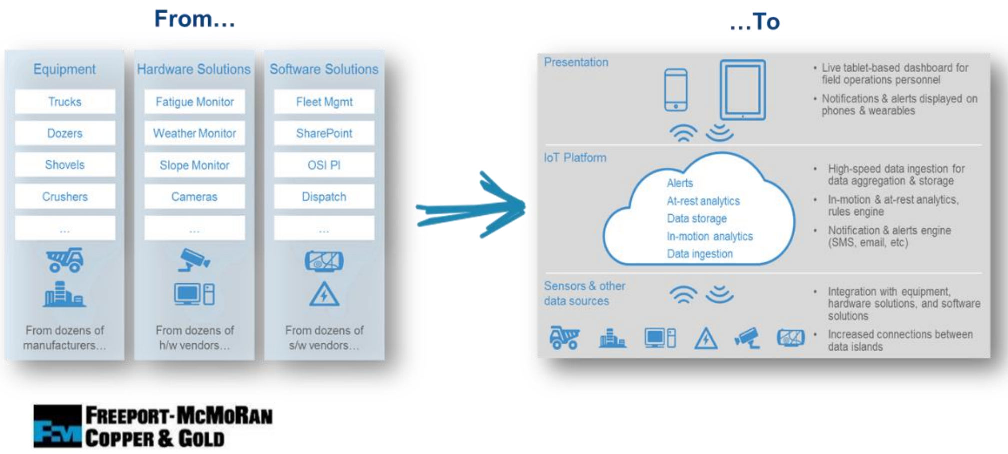

Figure 3. 5 From..To Freeport-McMoran Copper & Gold

3.4. Connected Workers

The introduction of the typical tools of the IIoT changes the way in which the different tasks are carried out, the working hours and places, the skills of the worker. Tablets, cameras and sensors provide remote monitoring of the plant.

The worker becomes the centre of the production process, trying to free him from physical fatigue and to focus his efforts on the work of creation and design.

Devices such as Smart Glasses, Smart Watches or Wearables in general, can be used to extend workers' skills, increase their knowledge or apply appropriate guided procedures, exploiting digital information embedded within the physical environment. (Daugherty, Carrel-Billiard, & Biltz, 2016).

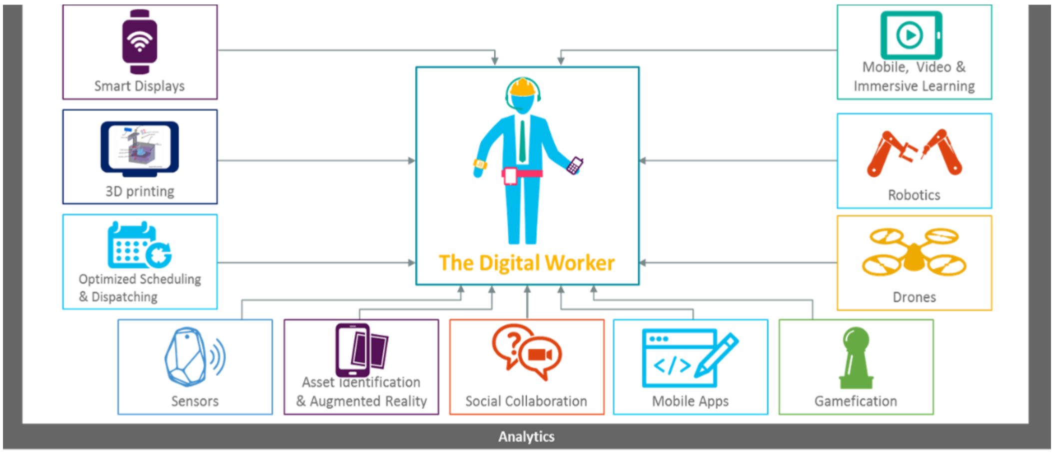

Figure 3. 6 Connected workers overview

The use of these devices also allows real-time monitoring of workers' safety and health, to identify in advance situations that are harmful to the operators, especially in environments that can be dangerous as happens in the mining or oil fields.

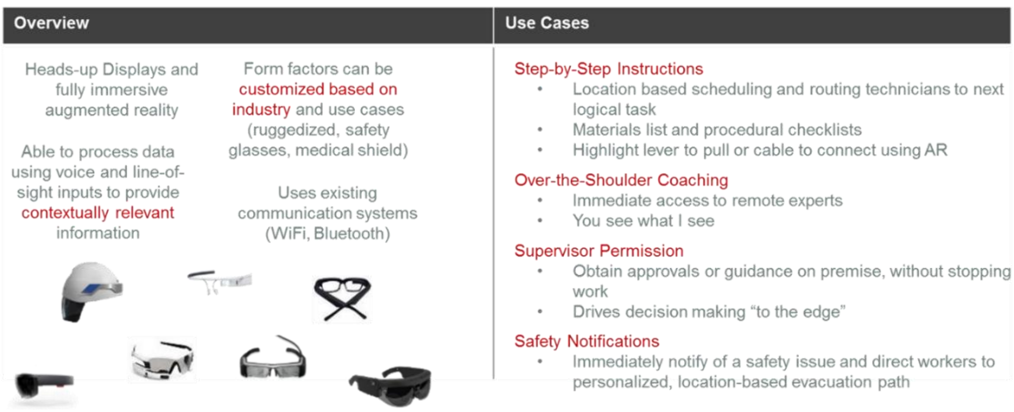

Figure 3. 7 Variable devices

The smart wearable displays shown in Figure above underline information and are designed to be worn on the body. The screens obtained are necessary to visualize the relevant context data coming from the connected platforms, from the assets, from the sensors, from the semi-automatic robots – nano drones and robots - and from the intelligent data acquisition systems for specific use-cases.

Alongside the wearables, the IIOT digital enablers are also the sensors and connected machines, smart devices capable of storing data such as smart phones, tablets, smart cameras and biomedical devices. The data obtained are sent to a Connected Platform integrated with ERP systems, to localize and exchange information between operators.

The European factories of the future will not only be required to provide global production competitiveness, but they must also be able to create a large amount of job opportunities for citizens.

The advantages deriving from the adoption of these technologies can be summarized in three fundamental points:

• Higher speed

- ❖ Accelerated training for new employees thanks to the visualization in time of increasingly intuitive work instructions
- ❖ Superior work performance due to fatigue-free workflow design
- ❖ Ergonomic hands-free work

• Minor Errors

- ❖ Intuitive graphical instructions optimized for the worker's individual skill set
- ❖ Use of additional modules and sensors such as scales, brightness sensors, voice control that help reduce the error rate, increasing process reliability
- ❖ Accurate work thanks to the use of comfortable tools for the operator and ergonomic working conditions

• Greater Flexibility

- ❖ Ease of adaptation to changes in the warehouse or production line thanks to a configurable workflow
- ❖ Possibility of combining different devices to optimally design the flow
- ❖ Constant implementation and integration of existing systems with AR technologies

3.5 Factor – Augmenting Technologies

“In contrast to factor – augmenting technological change, the substitution of machines for labor in additional tasks always reduces the labor share in national income and can reduce the equilibrium wage” Daron Acemoglu Department of Economics.

“Most economic models formalize technological change as factor augmenting (meaning that technological progress acts as if it increased the effective units of one of the factors of production) or as Hicks neutral (which leads to a proportionate increase in the output obtained from any input combination). Several authors, including Kotlikoff and Sachs (2012), Graetz and Michaels (2015), and Nordhaus (2015), also model automation as capital-augmenting technological change, which assumes that automation should be thought of as embodied in more productive (or cheaper) capital, which will then substitute for labor in a process governed by the elasticity of substitution. Bessen (2017), on the other hand, argues that automation mostly increases the productivity of labor and model’s automation as labor-augmenting technological change.

We argue that these approaches miss a distinctive feature of automation: the use of machines to substitute for human labor in a widening range of tasks. “(Acemoglu and Restrepo, henceforth AR, 2016, 2018).

Supposing Y to be the output:

$$Y = F(A_K K, A_L)$$

Where: F is continuously differentiable and concave;

K is the Capital

L is the Labor

A_K represents the Capital – Augmenting technology

A_L represents the Labor – Augmenting technology

The competitive labor market implies that the equilibrium wages are equal to the marginal product of labor:

$$W = A_L F_L(A_K K, A_L L)$$

The share of labor is given by:

$$S_L = \frac{W\,L}{Y}$$

Finally, thanks to constant return to scale, the capital share is $S_K = 1 - S_L$.

Capital – Augmenting

Suppose we consider automation as a driver for the capital – augmenting due to a technological change. The impact on the wage is given by:

$$\frac{d\ lnW}{d\ln A_k} = \frac{s_k}{\varepsilon_{kL}} > 0$$

Where

$$\varepsilon_{kL} = \frac{d\ln(\frac{K}{L})}{d\ln(\frac{F_k}{F_L})} > 0$$

The formula above represents the elasticity between labor and capital. Thus, technological changes made labor demand increase. The increase in capital reduces the labor curve only if $\varepsilon_{kL} > 1$.

So, automation will never lead to labor demand reduction or equibrium wage, but an increase in the labor share.

Labor – Augmenting

We can state the following ratio to be positive

$$\frac{d\ lnW}{d\ln A_L} = 1 - \frac{s_k}{\varepsilon_{kL}}$$

Thanks to $\varepsilon_{kL} > s_k$. This implies the increasing in the equilibrium wage and the lowering value of the substitution's elasticity. The result is negative just if $\varepsilon_{kL} < 1$.

Then, labor increasing due to technological change has a bilateral impact: it increases the labor demand and equilibrium wage but reduces the labor share.

Considerations

Furthermore, according to the theory of Zeira (1998), Acemoglu and Zibotti (2001) and Acemoglu and Autor (2011) the final output is identified by matching the services of a range of tasks, represented by a continuum:

$$Y = \left(\int_{N-1}^{N} y(i)^{\frac{\sigma-1}{\sigma}} di \right)^{\frac{\sigma-1}{\sigma}}$$

Where σ is the elasticity of substitution between tasks.

In conclusion, the study demonstrates that Automation:

- Increases productivity and output per worker
- Reduces equilibrium wage
- Increases the demand for capital and the equilibrium rental rate

3.5. Towards the validation of the model

After completing the literary revision that constitutes the foundation of the model, it is essential to prove the study to verify how much it is applicable to real cases.

All the cases presented in the second part of this model are Proof of Concept or experiments that the analysed companies are currently carrying out in order to evaluate the impact of the IIoT on their specific reality.

These are case studies developed in Accenture and to preserve customer confidentiality, the specific names of the clients analysed will not be explicit.

Chapter Four

Open Innovation

With Open Innovation is meant a firm approach to R&D strategy. It encompasses several strategies for accessing and developing competencies by looking outside the boundaries of the firm. The term has been coined by Chesbrough's seminal work in 2003. He identified an emerging practice by a number of large corporations and Procter and Gamble is the best example among them.

Usually, large firms implement their projects basing on closed funnel approach: they start an elevated number of projects but just a few of them reach the end of the funnel and get positive results.

Firms believe to increase productivity by spending their effort on R&D and decide to allocate part of their budget for projects with external entities. The number of fail projects can reach new markets and create space for the external proposals. The crucial point is to use external competences, which are not core for the firm and try to replicate them. "Measurement errors (false positives, false negatives) are likely to arise from judgments about the commercial potential of early-stage projects. Most companies' policies consciously limit "false positives" in assessing a project's commercial potential, but few companies take steps to manage the risk of "false negatives."
New metrics may help a firm focus more upon external sources of innovation to enhance its business model and enable the firm to salvage value from false negatives that otherwise would be lost."
Managing Open Innovation - Henry Chesbrough Jan 2016
Furthermore, R&D entities were pushed to find out revenues from lost projects by using licensing or spin-offs. The resulting "open funnel" model is shown on the right side of the next figure.

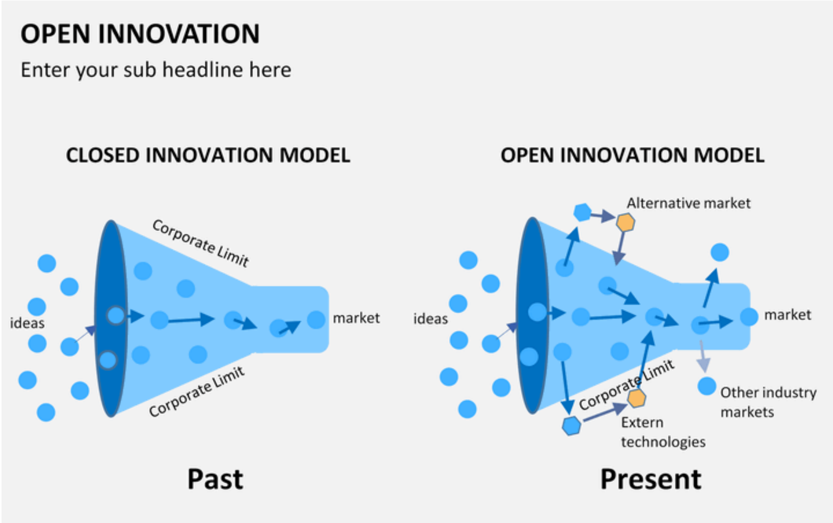

Figure 4. 1 Closed vs Open Funnel

This approach to managing competencies requires some commercial intelligence tools to establish an efficient agreement with external entities. Among the most common entities, firms can consider:

- Competitors - They could accept an offer to collaborate on specific projects, to profit from unused capacity, or to create returns from capabilities they have developed.
- For-profit organizations - Some industries perform outsourced R&D activity. Each industry has its own business term to reach the cooperation. Some industries might refer to Engineering Services Providers, while the pharmaceutical industry uses the Contract Research Organizations.
- Universities and non-profit organization – academic entities are interesting candidates for the context of Open Innovation strategies, especially when dealing with competencies and activities that are related to the upstream phases of the innovation process. This phenomenon is knew as technology transfer, and it leads to several approaches for cooperation with industry, such as licensing of intellectual property or performing contract-based research. Furthermore, academic organizations may temporary lead with the creation of spinoffs, based on internal technology or know-how with the purpose of enabling relationships with industry.

- Individual inventors and startup. Usually small entities are unable to fully exploit the inventions. The same holds for individuals who have developed specialized competencies internally and are not able to sell them in a business alone. On the other side, a firm interested in a particular technology may therefore find easier and less expensive to cooperate with the inventor, rather than replicate it internally.

Open Innovation seems to be a very attractive concept. However, the crucial problem is linked to the transaction costs a firm seeking for a solution will encounter in finding the right solution and creating an agreement that will be consistent for both parties.

The different mechanisms for Open Innovation can be classified according to two axes - Pisano and Verganti (2008). The first is the openness of the system, which can range from closed invitation-based mechanisms, which require ex-ante knowledge of potential solvers, to open mechanisms where virtually any potential solver is free to apply, and which require the capability to screen and select them ex-post. The second axis is the governance mechanism, which can range from strictly to flat, in which decision-making is shared between the seeker firm and the group of solvers. The first requires a well-defined innovation strategy while, in the latter, the firm uses the community not only as a source of competencies, but also as a contributor for defining innovation strategy.

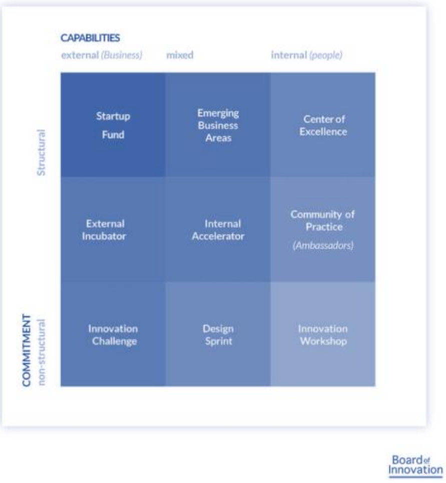

Figure 4. 2 Innovation Matrix

4.1 Open Innovation and AI applied to a real Case Study

There are four main actors which have different roles in the process:

- Accenture
- A Corporate
- A Start up incubator
- A Start up

We are going to deep explore the solution raised thanks to the interaction between Accenture and the Startup incubator; they both knew their client's needs and were able to match their interest in order to find a perfect compromise.

- Accenture, as the majority of you know, is the largest business consulting firm in the world and provides services on management consulting and technological implementations, also in outsourcing.
- The incubator works as a "growth ecosystem" which selects and invests in digital B2B software companies and gives them financial advices.

The problem they matched regards the optimization of the production planning in a plant.

- The corporate is organized in different Business Lines and produces a panel of finite products. It was interested to an algorithm able to be fast and based on detailed forecasts for the production planning and scheduling release.

4.2 As Is

Before tool enactment, the production in the corporate worked with an Excel file (see Figure 4.2) which was updated day by day by an engineer called production planner.

Each day the operator might extract the total overall of orders not yet released and decide what to schedule in the current day.

The decision has some constraints:

- Client request: when the client asks the final product (delivery date)
- Order feasibility: it depends by the availability for the production components
- Planned order start date: if the date is after the current one, the order is in delay; the same date means the order is on time; otherwise, if the date is before the current one it is early.
- Average daily product quantity: it is given by the coverage day of the plan and the number of days included in the coverage. (i.e. if we have 10.000 orders to release of the product A in the current plan and the plan should cover 5 release days, we have to schedule 2.000 pieces of the product A at a day, in average).
- Industrial constraints: technical requirements such as maximum possible quantity that can be released each day on the specific manufacturing operation.

The Figure below is an example of the existing scheduler utilized in the plant. We can see that the production planner must write in the red column the number of orders that decide to release, and those values goes to implement the card above.

He also asks forecasts to the material planner team for the orders which have expired and not yet feasible.

CLUSTER	TARGET	APER	SCHED	BRAND	TARGET	APER	SCHED		TARGET	SCHED
Cluster A	587	2661	1119	MacroBRAND A	5.240	28144	5226	Vincolo 1	2.837	3509
Cluster B	104	570	40	MacroBRAND B	3.877	17005	3924	Vincolo 2	62	0
Cluster C	426	1743	525					Vincolo 3	588	1017
Cluster D	246	1000	260	Product 1	215	1043	0	Vincolo 4	1.523	**1538,00**
Cluster E	457	2194	500	Product 2	695	2909	1094	Vincolo 5	**1200,00**	**1144,00**
Cluster F	39	160	160	Product 3	0	0	0	Vincolo 6	**556,76**	**520,00**
Cluster G	1.219	6851	1200	Product 4	1.095	6181	1660	Vincolo 7	5	0
Cluster H	2.004	8895	1964	Product 5	1.929	11426	1795	Vincolo 8	546	480
Cluster I	1.492	9111	1208	Product 6	1.643	6002	1705	Vincolo 9	1.004	1130
Cluster L	1.703	7731	1838	Product 7	0	0	0	Vincolo 10	1.356	1526
Cluster M	3.451	15349	3091	Product 8	0	0	0	Vincolo 11	2.436	2742
Cluster N	3.842	15311	3917	Product 9	525	2135	37	Vincolo 12	43	40
TOT	9.117	45149	9150	TOT_PF	9.117	45149	9150	Vincolo 13	5.356	4994
	GG	5,0								

Scheduled	Product	Feature A	Feature B	Order Quantity	Confirmed Quantity	ATP Result	1° Check	2° Check	N.ORDER	Planned Start Date
	Product 9	54	004	40	40	OK			1803173559	29/08/2018
	Product 1	57	95/31	117	117	OK			1803452670	31/08/2018
	Product 1	53	KHR1O1	100	100	OK			1803148602	31/08/2018
20	Product 6	52	007	20	12	PT			1803177684	30/08/2018
60	Product 8	45	002	60	60	OK			1803454111	05/09/2018
	Product 3	55	KHR1O1	100	100	OK			1803045907	02/08/2018
80	Product 4	45	003	80	80	OK			1803454216	05/09/2018
	Product 7	52	24/86	60	9	MS	OK	OK	1803448741	03/09/2018
	Product 8	52	1052S3	40	40	OK			1803449292	04/09/2018
80	Product 9	45	004	80	80	OK			1803451922	06/09/2018
40	Product 2	45	003	40	40	OK			1803454280	06/09/2018
	Product 2	54	003	60	60	OK			1803173617	29/08/2018
100	Product 4	45	003	100	100	OK			1803454404	06/09/2018

Figure 4. 3 Existing scheduler example

4.3 The value added of the Startup

In order to ensure a competitive advantage, the startup proposes an optimal solution, to simplify and solve the problems linked to the production planning and detailed scheduling (PP&DS). It is possible to build complex workflow and analyse calculations with few clicks. The software has a friendly interface and results intuitive. The young firm proposes elements based on Artificial Intelligence applied to a sophisticated algorithm. The program has the objective to save time and resources, by reaching new levels of efficiency.

The startup studied the Corporate's production, it analysed each finite product and propose a solution for the right allocation of semi-finished and finished products on the lines and on the warehouse.

There is a delivery date fixed by the client requests, suppose it to be on day x. The final product must be assembled and ready for delivery on x-1 day. In order to ensure this point, the components which form the final ones must be ready as soon as possible in order to avoid buffers; the same reasoning is for the raw materials, available for the production of the single component. The tool minimizes buffers and optimizes the planning of the phases, updating the schedule if necessary.

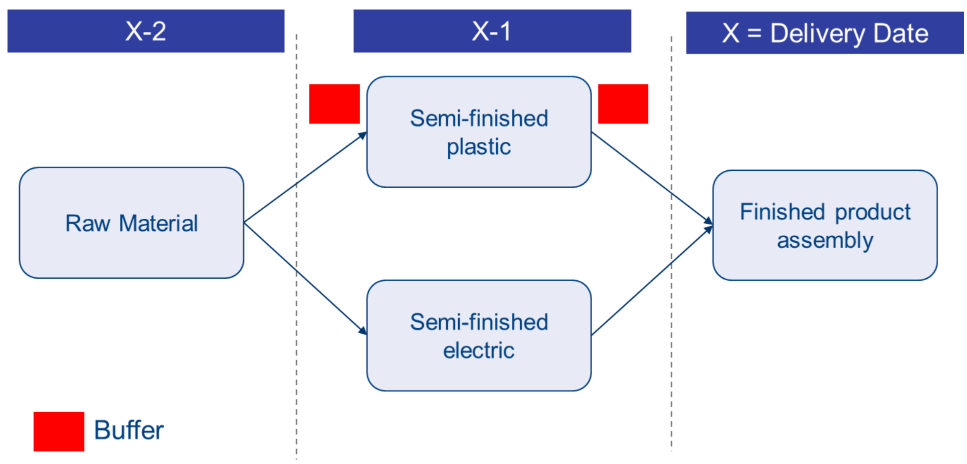

Figure 4. 4 Problem Scheme

4.4 How Accenture enters the process

Accenture provides support and maintenance services for the implementation and the global rollout of the selected tool. The solution will define a core model to be implemented in the first pilot and progressively expand through Business Lines and Plants, involving Apac, Emea, Latam and Nafta markets. The Corporate produces a lot of different products, so it has several business lines all over the world and the purpose is to expand the software overall the different contests.

Accenture has the objective to drive value as a System Integrator, thanks its knowledge of all the processes of the firm and the deep understanding of manufacturing and supply chain environments.

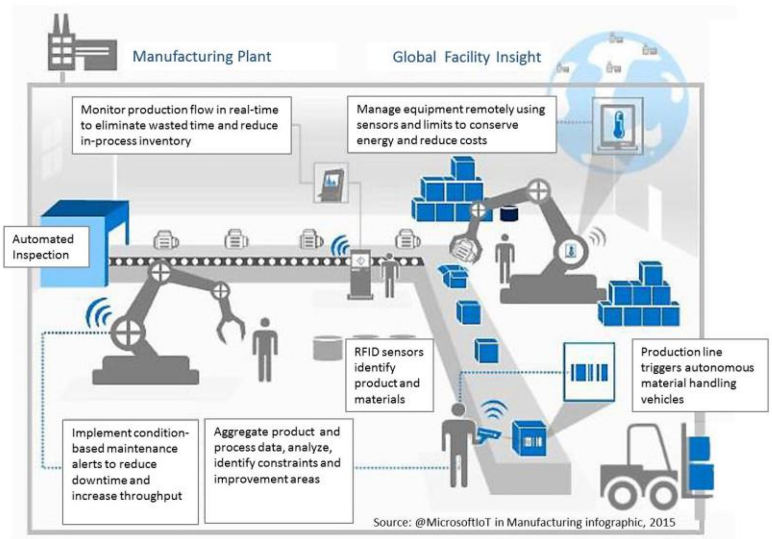

Figure 4. 5 AI in a Manufacturing Plant

4.5 The application

The tool optimization works with some constraints:

- Client deadlines
- Production capacity

By taking into account each setup time for the different machines.

There are also some constrains linked to exogenous factors such as:

- How many orders are performed, how many products completed
- Which products are produced
- Which is the material utilized

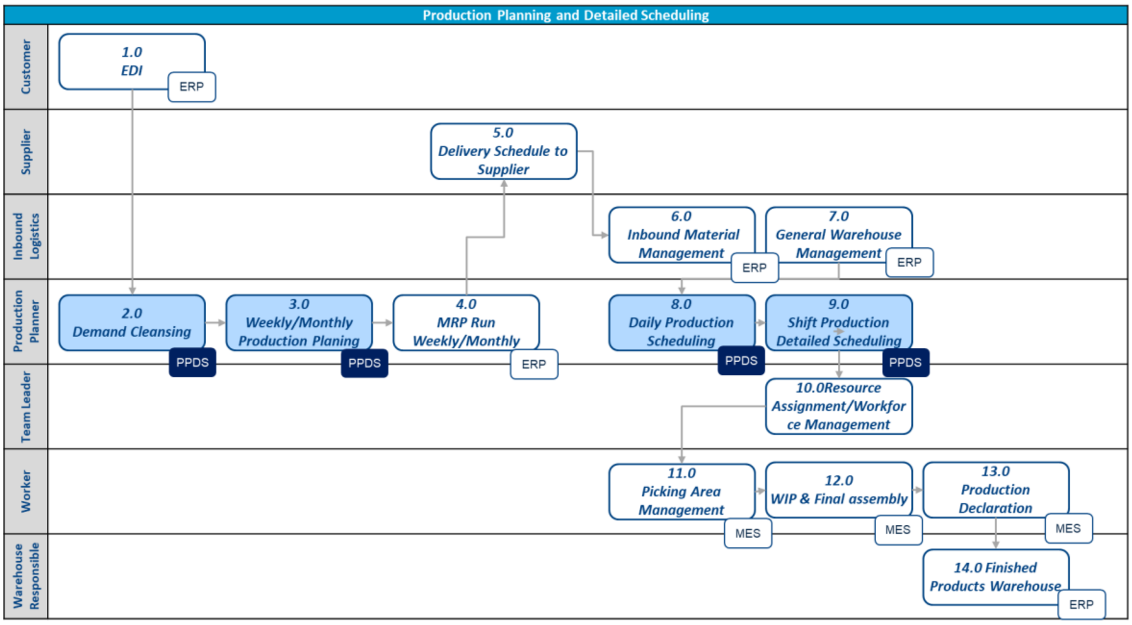

Figure 4. 6 PPDS High Level Process

The process follows the flow reported in Figure 4.5 and has two main features:

- Weekly and Daily medium/long term production planning: based on customer demand (executive and forecast orders) received in ERP and rough-cut capacity planning, the Master Production Schedule is elaborated to define what finished products should be produced, in what quantity and when in order to meet customer expectations and inventory levels objectives.

  The MPS output is sent back to ERP for MRP run and purchase orders creation towards suppliers;

- Detailed short-term production scheduling and sequencing: daily or at the beginning of a production shift the detailed production plan for finished and semi-finished products is defined according to the finite capacity (machine, manpower and materials) and detailed constraints (production mix, production lots, changeover time limitation, etc.).

  The production plan is sent to RAD for production execution and control process.

In other words, there is the parallel planning of semi-finished and finished products: if the final product is A+B, and B is in delay, the tool recalculates the production planning by considering eventual problems linked to the single components (semi-finished). In the case in which B has some problems so that the final product is not performed in the right times, the algorithm rearranges the component to be produced and the production shifts.

This is a dynamic tool, it updates basing on the constraints and change the output by considering historical data.

The tool takes the output from the precedent solutions and report them as an input of the new ones, so it enables the possibility of stochastic forecasts.

The solution supports BLs in the execution of the activities of scheduling and planning managing finite capacity, constraints in the industry, resources, leveraging stocks and material according to costs and time.

The solution is in charge to support:

- Medium/Long term production planning both daily and week thanks to ERP forecasts.
- Short term production sequencing, the production plan for semi-finished and finished products is estimated tanks to the finite capacity and constraints such as production lots, mix of products or limitations based on time.

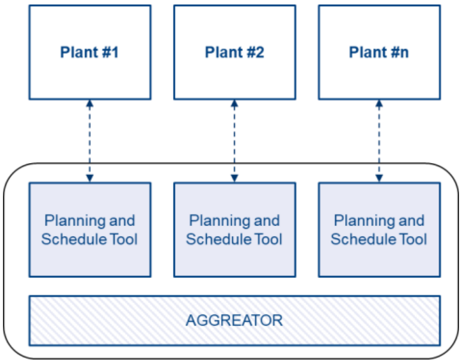

Figure 4. 7 Normalization Tool

There is an aggregator which receive and normalize data from different plant.

4.6 Agile Approach

The approach that will be used is the Agile ones. For the first pilot we used a waterfall method, with multiple release based on the requirements; the rollouts instead will be implemented in agile methodology.

It provides to access the direction through lifecycle. There are regular cadences of work, the sprints or iterations, and at the end the teams should present the improving they made to the project. It is an iterative or incremental technique, thanks to the short cycle of which it is composed. The main difference respect to the waterfall method, is the possibility to iterate and to change the mind, while in the waterfall the team has just one chance to get each aspect of a project right. The agile paradigm revisits every time the requirements, the design and the salient aspects of the project, so it is continuously improved and modified.

This method saves a lot of money on the development side and time to market. Each work cycle is of three weeks, is very short and in this way agile helps companies to get the right product. We want to use this approach to be as competitive as possible in the marketplace.

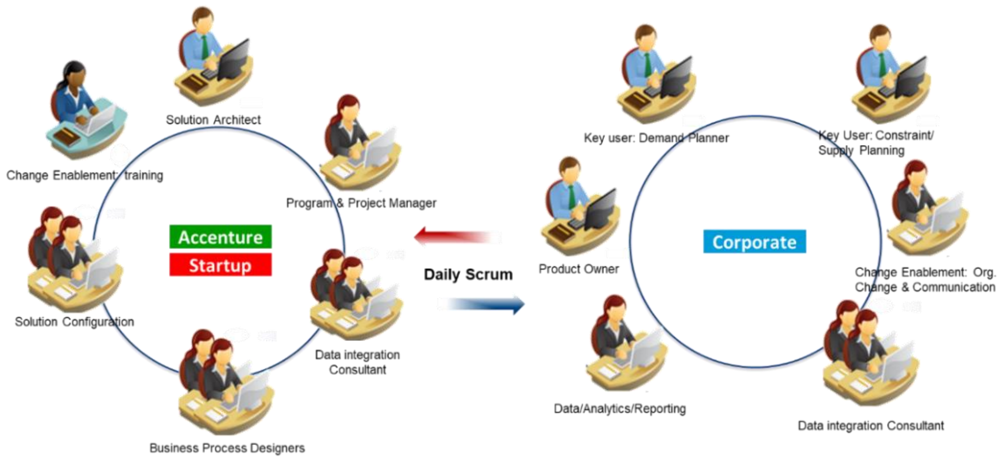

Figure 4. 8 Agile Changes Enablement

To introduce agility, we face up with the concept of *Scrum*, it is the most popular way to be simple and flexible. The accountabilities of the manager are splatted into three scrum roles:

1. Product owner
2. Development team
3. Scrum Master

The first is in charge to represent the business value of the project; he is responsible for working with both groups.

The second is responsible of the actual work, the team is cross functional.

The scrum master is the facilitator, he is accountable for helping the team to reach approval for what can be achieved during a specific period of time, he ensures the productivity of the team.

The main steps are:

- *Product Backlog*, it is dynamic. It changes following product needs to be competitive and useful.

- *Sprints,* a set of periods of time during which specific work must be completed and be ready for review. Each sprint starts with a meeting.
- *Product Incrementation,* improvements applied to the product at the end of each sprint.

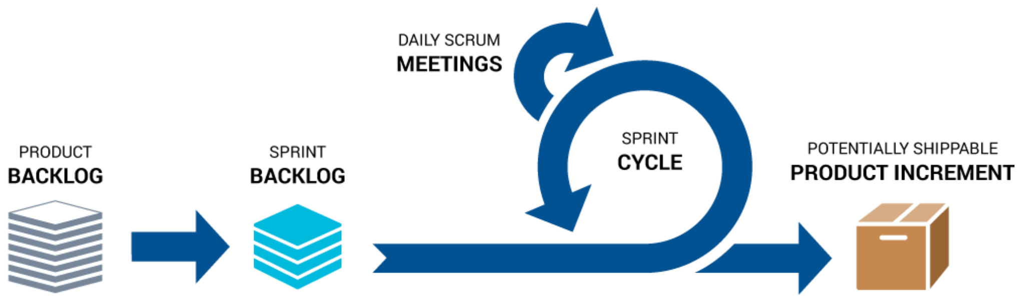

Figure 4. 9 Scrum and Sprint

There are four project activities, specific for agile:

1. *Sprint planning*, the most important meeting in this methodology where the products backlog is analysed to understand which kind of features can be joint in a single sprint and then they are subdivided during the sprint timeline.
2. *Daily scrum,* daily meeting to share info about issues and progresses; it is the only formal meeting during the day, all the other one is informal and taken face to face in a communication level.
3. *Sprint review,* the product owner is informed regarding the progresses and what has been performed during the sprints. It is a crucial point where the product owner decides to push forward the product into next stage or requires a rework into another sprint.
4. *Sprint retrospective,* the team analyses the product at the end and think about new ways for improving it, again and again. This activity is executed thanks to the project experience and enables the progressively enhancement of the work sprint by sprint.

Role	Product Owner	Scrum Master	Team
Events	Sprint planning Daily scrum (optional) Sprint review Sprint retrospective (optional)	Sprint planning Daily scrum Sprint review Sprint retrospective	Sprint planning Daily scrum Sprint review Sprint retrospective
Artifacts	User stories Product backlog	Impediment log Continuous improvement log	Estimates Sprint backlog Sprint burn-down Release burn-up
Rules	Creates and maintains the user stories, updates and prioritizes the product backlog	Coordinates the daily scrum and the retrospective team Remove impediments Acts as a coach for the team	Estimate each user story Decompose the backlog into tasks and plans the Spring Collect and monitor Sprint progress through agile metrics

Figure 4. 10 Scrum table

The main agile values are applicable in each agile environment:

Inspect and adapt: the product is constantly elaborated through a progressive enhancing loop, which provide input for the new cycle and achieve optimization.

Transparency, every single documentation is kept available for everyone, so that the people involved in the process can understand the steps, what has been updated and why. The documents are not protected, there is not a hierarchy to follow to access them.

Perseverant improvement, another important factor which may help the product optimization is the better tailored sprint, cycle by cycle.

Scrum meeting helps the team to follow process' rules, but we were missing the key point of adaptation. It is the ability to manage and solve unpredictable problems raised during the process. Adaptation is a way to be and the people working on this methodology should adopt it as a lifestyle. I want to underline the values of commitment, courage to take decisions, open minded and respect that team's members must have.

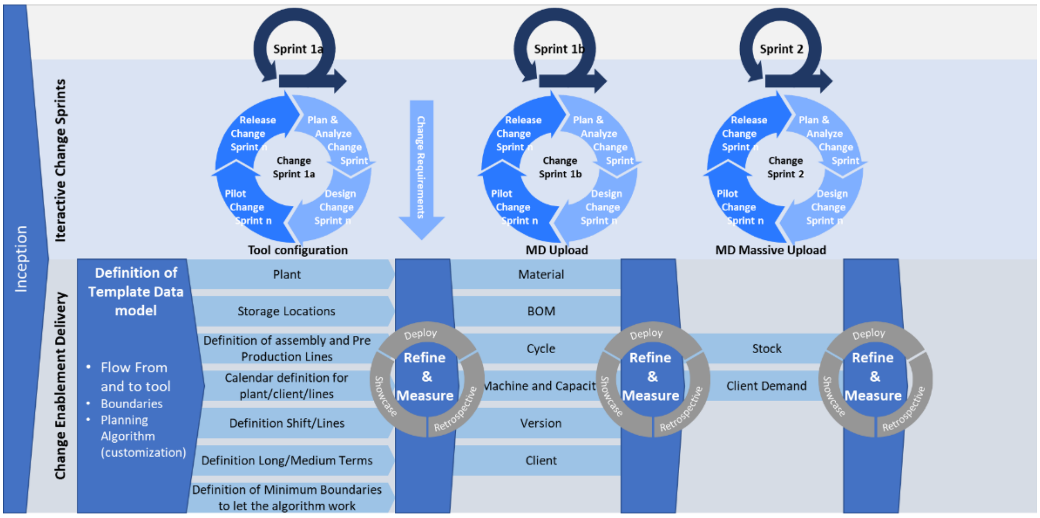

Figure 4. 11 Change Enablement Delivery and Interactive Changes Sprints

4.7 Project Phases

At the beginning there is the study of the solution design and the data integration analysis. Accenture and the software vendor provide a demo target for demonstrate the support configurations for the corporate requirements. The key activities are:

- Integration and analysis definition
- Model and data mapping
- Configure and test the functionalities in according with requirements
- Execute customization and detailed design
- Capture results and solve defects

The transaction phase between the system requirements validation and the use of it for successful adoption consists of:

- Training
- Simulation
- Post support maintenance

The implementation follows the roadmap:

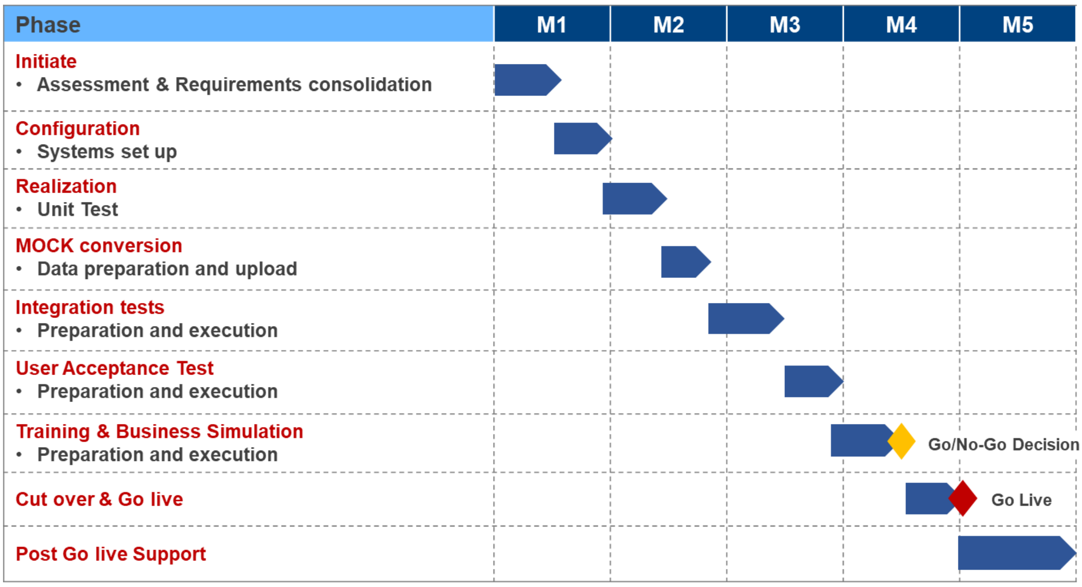

Figure 4. 12 Rollout in a BL

Chapter Five

Final Considerations

Industry 4.0 is an incredible opportunity for manufacturing industries and for national economies.

The most competitive companies today are those that develop new products, new services and new business models. They are also the most productive, willing to invest in innovation to improve their returns and exploit the potential of the new smart devices.

It is essential to be flexible and ready to face change trying to exploit the available resources and creating the frame necessary to effectively use all the tools available. In the case we talked about open innovation, agile approach, contemporary revolutions and this must be the next direction; be innovative, flexible and open minded.

The Industrial Internet of Things involves increasingly interconnected products, the factory, productive and efficient, and people who become an indispensable tool for monitoring the production.

5.1 Benefits

The solution allows the Corporate to

- Manage a long-term production
- Face with emergencies, before a machine gives defectives output the algorithm schedules the maintenance task
- Be custom, each line or machine can have its own algorithm based on the data its processes
- Help the production planning to decide which are the priority orders and which can be performed in a second moment

- Optimize the stock, it is an expense for the corporate and of course a stock minimization creates saving for the firm
- Minimizing of wip
- Monitor the production plant
- Face with unexpected events to reschedule real time the production and redefine the overall calculation for OEE's plant
- Increasing of the level of service give to the clients in terms of speed, on time availability and quality of deliverables.

5.1.1 Results quantification

	Baseline	Benefits
Manufacturing Execution	• Improve OEE • Reduce Downtown • Reduction in safety Related Incidents • Productivity Improvement due to AI	2% 35% 4% 10%
In-Plant Logistics	• Inventory Optimization • Time Reduction for remote parts programming • Reduce Tooling Inventory	25% 25% 40%
Next Steps		
Predictive Maintenance	• Total Maintenance Costs • Reduce Overall Tooling Maintenance Costs • Additional optimization due to Predictive Maintenance (Parts and Labor) • Usage based Design	10% 12% 5% 5%

Figure 5. 13 Results summary

5.2 Next steps

Manufacturing demonstrates enormous potential to generate wealth, create high quality products and highly skilled jobs.

The study of the elaborate has important next steps, it enables the technology to

1. Help a corporate to manage personnel turns

2. Cross the production panning with the production maintenance → predictive maintenance
3. Make a real time machines' monitoring
4. Evaluate KPI, during the time in which the machine works

Given the progress in Artificial Intelligence, in Automation, in Robotics and in the Internet of Things, the world has entered a new industrial era. All this is not science fiction or a prediction for the next century. The fourth industrial revolution is here and now.

Figure and Table Index

References

- Louis Columbus, Forbes 2018
- Purdy & Davarzani, 2015
- Use Models to Accelerate Your Industrie 4.0 Initiative, Gartner 2018
- Brettel, Friederichsen, Keller, & Rosenberg, 2014
- Webster, 2015
- Liongosari, Mullan, & Müller, 2016
- Manyika, et al.
- O'Halloran & Daugherty, 2015
- Proverb, the six strategic levers to optimize the productivity of plants and industrial assets, 2015
- Ministero dell'Economia e delle Finanze website
- Revelli, 1993
- Ohno, 1988
- Kyoto guru the secrets of the WCM, 2010
- Womack & Jones, 1997
- Womack J., 2011
- Rother & Shook, 1999
- Naples & Tonchia, 2009
- Womack J.P., 1990
- Gröbner, 2007
- Bhaskaran SR, Krishnan V (2009) Effort, revenue, and cost sharing mechanisms for collaborative
- new product development. Manag Sci 55(7):1152–1169
- Boudreau K, Nicola L, Lakhani K (2011) Incentives and problem uncertainty in innovation
- contests: an empirical analysis. Manag Sci 57(5):843–863
- Cassiman B, Ueda M (2006) Optimal project rejection and new firm start-ups. Manag Sci 52 (2):262–275

- Chesbrough H (2003) Open innovation: the new imperative for creating and profiting from
- technology. Harvard Business School Press, Boston
- Cuervo-Cazurra A, Un CA (2010) Why some firms never invest in formal R&D. Strateg Manag J
- 31(7):759–779
- Dushnitsky G, Lenox MJ (2005) When do firms undertake R&D by investing in new ventures?
- Strateg Manag J 26(10):947–965
- Dushnitsky G, ShaverJM (2009) Limitations to inter-organizational knowledge acquisitions: the
- paradox of corporate venture capital. Strateg Manag J 30(10):1045–1064
- Hoang H, Rothaermel FT (2010) Leveraging internal and external experience: exploration,
- exploitation, and R&D project performance. Strateg Manag J 31(7):734–758
- Hoetker G, Mellewigt T (2009) Choice and performance of governance mechanisms: matching
- alliance governance to asset type. Strateg Manag J 30(10):1025–1044
- Knott AM (2008) R&D returns causality: absorptive capacity or organizational IQ. Manag Sci 54
- (12):2054–2067
- Management of Innovation and Product Development – Marco Cantamessa, Francesca Montagna
- Industry X.0 – Realizing digital value in industrial sectors – Eric Schaffer
- Acemoglu and Restrepo, henceforth AR, 2016, 2018
- Year 2035: 400 Million Job Opportunities in the Digital Age, Deloitte series on Industry 4.0

- Forecast: The Business Value of Artificial Intelligence, Worldwide, 2017-2025, Published: 12 March 2018
- The Economic Impact of IoT PUTTING NUMBERS ON A REVOLUTIONARY TECHNOLOGY, Frontier Economics, March 2018
- Disruptive technologies: Advances that will transform life, business, and the global economy. McKinsey Global Institute, May 2013
- Predicts 2018: Industrie 4.0 and Advanced Manufacturing. Published: 9 April 2018, Analysts: Bettina Tratz-Ryan, Alexander Hoeppe, Pete Basiliere