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Gli aspetti della gestione del cambiamento nell'integrazione delle tecnologie emergenti: il caso della manifattura additiva

Change Management aspects in integrating Additive Manufacturing.

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1. INTRODUCTION TO CHANGE MANAGEMENT

Today change is constant and organizational leaders who anticipate change and react rapidly and responsibly are successful. Keeping pace with continuous improvement increases the competitive advantage and profit maximization. One of the ideal approaches to achieve these objectives through the rapid change in technical communication and information is managing change within the organization.

Change management is defined as the planning and coordination process of individuals, teams, organizations in order to allow a transition from a current structure to a desired future. In this transition, the change management process must take into consideration complex variables and implement the resources available with the plan or system it has developed. The implementation, and therefore the thrust and facilitation provided by change management towards this studied transition, arises from the need to be reactive on the market and sensitive to the complexity of management systems optimized at best. Among the many variables that must be considered and harmonized, change management has the task of weighing the effects of its intervention in a very complex ecosystem, as already mentioned. To get an idea of this complexity, it is enough to consider only a few elements that must be taken into consideration, such as the people directly involved in the process of change, society, the evolution of technology, competition, the goals to be achieved. In this complexity, change management has both a predictive role (and therefore of analysis and development) and of facilitating and managing the pre-established change.

Moreover, two further preliminary distinctions must be made about change management. The first concerns the subjects involved in the change and the specialized sectors that have dedicated themselves to them. As already mentioned, the change and transition from an initial state to a subsequent one can be active or passive and concern an individual, a company, or an organization. Based on the subject considered, the research is conducted by the respective specialist sectors, including sociology, political science, economics, engineering, psychology (just think of the studies on trauma, such as, by way of example, that of Ross on the phases concerning grief or Freud's Beyond the Pleasure Principle, in which the analysis of traumas and more or less effective transitions of the psyche becomes particularly speculative).

The second distinction concerns the time of change. Based on how far the transformations to be obtained are distant in time, it is customary to distinguish between "change management" and "change project". The "change project" concerns the management of change with set objectives and limited resources according to time (and therefore deadlines), budget and workforce.

Change management, on the other hand, is a continuous process of study and direction towards transformation and innovation in a proactive way. It too can be active, (and therefore willing to innovate first with the necessary precautions), or passive, and in this case the implementations could be left to chance or implemented only partially, thus increasing the chances of a failure in the long term. These last distinctions concern above all the economic-business sector which in fact will be the one that we will deepen more in this thesis following an engineering perspective.

The causes that require immediate change response are various. They can be environmental causes, such as earthquakes or other natural disasters, pandemics, or even they can be causes resulting from acts of terrorism, or they can be macro-environmental, such as for major economic and political changes, technological advances and turbulences, the rapid expansion in the global market and the alterations of demographic and social structures.

Organizations go through various internal change processes during their normal life cycle in which organizational leaders - those with the power to direct and implement change policies - can create forces that drive change within the organization. A common example concerns those companies that, in order to initiate a process of change that revitalizes the business, start a radical change towards the relationships in the corporate hierarchy (reporting structure). In this way, an attempt is made to revitalize market orientations with an internal structural change. Other changes such as mergers and acquisition, new top management teams and changing company dynamics because of reorganization and restructuring require organizations to make significant changes not only in strategy and structure, but also in organizational culture and processes. And, in this sense, it is worth mentioning Crawford, L. & Nahmias, AH 2010 in “Competencies for managing change” where, in a case study involving three companies dealing with change, in addition to the importance of project management and change management, it emerged that the human factor was as important as technical skills, and this precisely to ensure an optimal transition towards effective innovation.

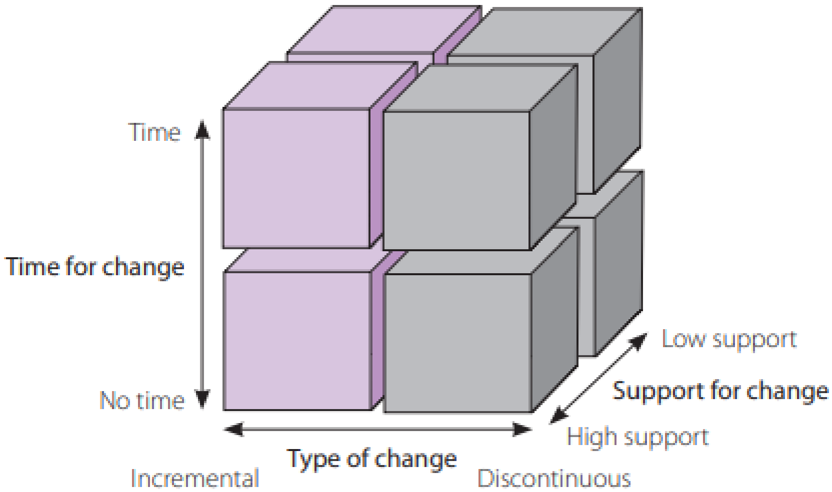


Figure 1: A three-dimensional model to aid choice of change strategy (John Hayes in “The theory and practice of change management”

1.1 FROM PROJECT CHANGE TO ORGANISATIONAL CHANGE

Organizations can thrive in a dynamic environment only if their speed of learning and changing meets the dynamics of their environment. Change management allows to build and reduce complexity as well as dealing with the dynamics of organisations.

The term “change” derives from latin “cambiare” it means the act or fact of change. Changes different, of different intensity and speed, and can occur at the individual, the group, the organizational, or the societal level. Change can be meant, in a strategic dimension, as it is the movement of a company away from its present state towards the desired future state to increase its competitive advantage and possibility to thrieve into the future.

The traditional life cycle models of organisations define situations, in which changes are required. The organizational growth model from Greiner (1972) e.g. differentiates the leadership crisis, the autonomy crisis, the red tape crisis, and the development crisis, as reasons for organizational growth. It is assumed, that changes (in the form of growth) are caused by crises.

Similarly, Pumpin and Prange (1991) and Bleicher (2004) relate their phases of the organizational life cycle (pioneer, market development, diversification, acquisition, cooperation, and restructuring phase), to crises situations. The management literature obviously focuses primarily on growth scenarios, decline as a development scenario of organizations does not seem relevant.

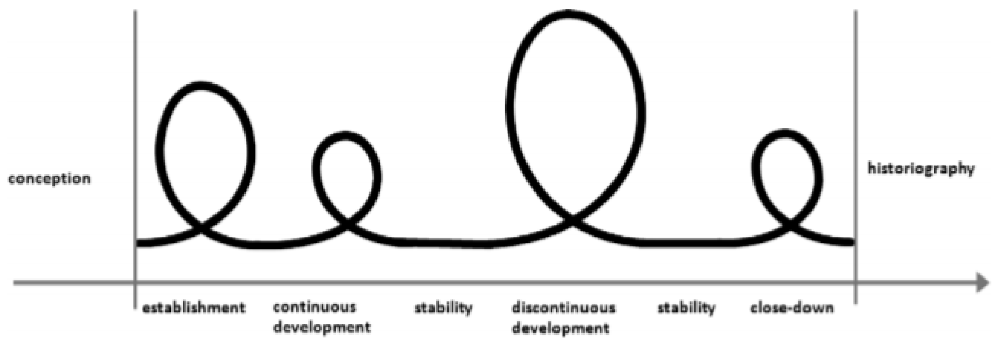


Figure 2. Evolution of the permanent organisation (Gareis, 2009)

Fig. 2 offers a more generic model, differentiating in the phases establishing, developing (continuously or discontinuously), stabilizing, and closing down.

This evolution model for organizations allows to focus on major reasons for change, such as developing a product, entering a partnership, building a plant, which require continuous development, and organizing a new ownership, acquiring, or merging, entering new markets, etc., which require discontinuous development. The conception (of a new organization) and the historiography (of a not anymore existing organization) are the context of the life cycle of an organization. From a systemic point of view reasons for changes can either be interventions from the relevant environments (e.g., shareholders, clients, suppliers) of an organization or its internal dynamics, based on the self-organizational capabilities of a social system. Self-organizational processes of a company are e.g., strategic planning and controlling, monitoring the environment, etc.

1.2 MODELS OF THE CHANGE PROCESS IN LITERATURE

In the dynamism of contemporary society, the ability to change an existing structure can often be a success factor. But if change and its management are so relevant, there are many ways in which these changes can be planned. Thus, each company will have to decide which course of action best suits their goals. In the literature on change management there are numerous proposals for operating models and in this chapter, we will try to report the most important.

However, it should not be forgotten that these models, as Todnem points out, are not without imperfections and, at times, also by the lack of scientifically exhaustive case studies, since they are often based on limited empirical experiences. The very nature of these methods must therefore make all those involved in change reflect on how important a varied and in-depth knowledge of the different models is and how much the analytical and predictive skills of individuals, combined with the continuous need to learn and improve, are fundamental to a good change management intervention.

A first distinction that must be considered concerns the extent of the change. Levy and Merry (1986) offer a development model for organizations which differentiates between "1st order change" and "2nd order change". The difference between these change types stems around the magnitude and the pace of change. 1st order changes are defined as "minor improvements and adjustments that do not change the system's core and occur as the system naturally grows and develops" (Levy and Merry, 1986, p. 5). A 1st order change is generally characterized by changes in functional processes, including organizational structure, technology, communication systems, recognition and reward programs, and decision-making processes. 1st order changes are implemented in the context of an organization's existing paradigm or metarules, which unnoticeably shape perceptions, procedures, and behaviours (Levy and Merry, 1986).

The 2nd order change is a multi-dimensional, multilevel, qualitative, discontinuous, radical organizational change involving a paradigmatic shift. It leads to a new identity of the considered organization. 2nd order change is viewed as discontinuous, deep structural and cultural change, while 1st order change is considered part of a continuous process.

A differentiation of change types relating to the ability to manage changes can be made according to Heitger and Doujak (2008). In a two-dimensional matrix, in which the vertical axes show the demand for change and the horizontal axes shows the potential to change.

1.2.1 ***Lewin Model***

Defining the phases of change management has a long tradition that dates to as early as the work of Kurt Lewin in 1947. Lewin developed a three phases model. The basis for change is a state of relative stability of an organization, which is transformed into a new stable state. This transformation should follow a three-steps procedure of unfreezing, moving and re-freezing the organization.

Before any change can be implemented, it must go through the first step of thawing. Since many people are inherently resistant to change, the goal in the unfreezing stage is to create awareness of how the status quo or current level of acceptance is hindering the organization in some way. Old behaviors, mindsets, processes, people, and organizational structures all need to be carefully examined to show employees how change is necessary for the organization to create or maintain a competitive advantage in the marketplace. In the unfreezing phase, communication is especially important so that employees are informed of the impending change, the logic behind it, and the benefits to each employee. The idea is that the more we know about a change and the more we feel it is necessary and urgent, the more motivated we are to accept it.

Once the community members in question are "thawed out," they can begin to move: The phase of change can truly begin. Lewin recognized that change is a process in which the organization must transition or move to this new state. This change step, also known as transitioning or moving, is characterized by the implementation of the change. This is the time when the change becomes real. Consequently, it is also the time when most people struggle with the new reality. It is a time marked by uncertainty and fear, making it the most difficult step to manage. During the change step, people begin to learn the new behaviors, processes, and ways of thinking. The better prepared they are for this step, the easier it is to manage. For this reason, education, communication, support and time are critical for employees as they become comfortable with the change. Again, change is a process that must be carefully planned and executed. Throughout this process, employees should be reminded of the reasons for the change and how it will benefit them once it is fully implemented.

The final phase is referred to by Lewin as freezing, although many refer to it as refreezing to symbolize the act of reinforcing, stabilizing, and solidifying the new state after the change. The changes made to organizational processes, goals, structures, offerings, or people are accepted and refrozen as the new norm or status quo. Lewin considered the refreezing step to be particularly important to ensure that people do not fall back into their old ways of thinking or acting before the change is implemented. Efforts must be made to ensure that the change is not lost; rather, it must be cemented into the culture of the organization and maintained as an acceptable way of thinking or acting. Positive rewards and recognition of individual effort are often used to reinforce the new state, as it is believed that positively reinforced behavior is likely to be replicated.

Some scientists argue that the refreezing step is outdated in today's business world due to the constant need for change. They believe it is unnecessary to spend time freezing a new state when it will likely need to be evaluated again and possibly changed again in the immediate future. Anyway, without the freezing step, there is a high probability of falling back into the old way behaviour. Usually taking one step forward and two steps back can be common when organizations overlook the refreezing step in anticipation of future change.

1.2.2 ***Kotter Model***

There exist, in the literature, a number of other change models to instruct and to guide the implementation of major change in organisations.

Another important and famous model is that of Kotter. Kotter developed a model that may be used at the strategic level of an organization. In aim to change its vision and step by step transform the organization. Some studies that have used this model have shown that the change process goes through a set of phases and each of them lasts a certain amount of time and has equal impact to the success of change. The model has eight stages and each of them focuses on employees' response to change. This is very interesting because it is precisely the workers, the people, the subjects who suffer most from the transitions from a state of comfort to one of momentary uncertainty. According to Kotter the eight steps to transforming an organization are as follows:

Establish a sense of urgency about the need to achieve change. People will not change if they cannot see the interior need to do so.

Create a guiding coalition. Assemble a group with positive and power energy and influence in the organization to lead the change.

Develop a vision and strategy. It's essential to create a vision of what the change is about and tell people why the change is needed and with that means it will be achieved.

Communicate the change vision. Tell people, in every possible way and at every opportunity, about the why, what and how of the changes.

Empower broad-based action. Involve people in the change effort, get people to think about the changes and how to achieve them rather than thinking about why they do not like the changes and how to stop them.

Generate short-term wins. Seeing the changes happening and working and recognizing the work being done by people towards achieving the change is critical.

Consolidate gains and produce more change. Create momentum for change by building on successes in the change, invigorate people through the changes, develop people as change agents.

Anchor new approaches in the corporate culture. This is critical to long-term success and institutionalizing the changes. Failure to do so may mean that changes achieved through hard work and effort slip away with people's tendency to revert to the old and comfortable ways of doing things.

As is evident, this model focuses on preparing employees for change rather than change implementation itself. The focus on employee experience and proper workplace communication is one of the reasons why this is one of the most commonly used change management models.

Anyway, Kotter's model should not be considered as success guaranteed because it should be integrated with emerging change models. As we mentioned earlier, Todnem (2005) stated "Theories and approaches to change management currently available to academics and practitioners are often contradictory, mostly lacking empirical evidence and supported by unchallenged hypotheses concerning the nature of contemporary organizational change management".

1.2.3 ***McKinsey model***

Another famous model that has been used since the 1980s is that of McKinsey's 7S Framework.

This system takes into consideration seven elements and the relationships that exist between them in order to make an organization perform at its best. The model can be used to understand how the organizational elements are interrelated, and so ensure that the wider impact of changes made in one area is taken into consideration: the seven elements need to be aligned and mutually reinforcing.

These are the seven elements that McKinsey consider in his model.

- **Strategy.** Strategy is the change management plan that should consist of a step-by-step procedure or future plan.
- **Structure.** This factor is related to the structure in which the organization is divided or the structure it follows.
- **Systems.** This stage focuses on the systems that will be used to complete day-to-day tasks and activities.
- **Shared values.** Shared values refer to the core or main values of an organization according to which it runs or works.
- **Style.** The manner in which change is adopted or implemented is known as 'style'.
- **Staff.** The staff refers to the workforce or employees and their working capabilities.

- **Skills.** The competencies as well as other skills possessed by the employees working in the organization.

The important aspect of McKinsey's model is that it focuses on business aspects that should be defined before the change strategy is implemented.

*1.2.4 **ADKAR model***

Another important people-focused approach to change is the ADKAR one. This model, conceived by Jeffrey Hiatt, aims to focus on how people change themselves or how they can best introject change. Even though this is a business-oriented goals, it can be very useful to support employees to go through the process of change more easily.

ADKAR is an acronym for:

Awareness: Awareness of the need to change

Desire: Desire to participate in and support the change

Knowledge: Knowledge of how to change

Ability: Ability to implement the change

Reinforcement: Reinforcement to sustain the change

Since organizational change is directly dependent upon its employees for successful implementation, it's critical for individuals to have a clear understanding of what changes are occurring, why they are occurring, and how they affect them personally. The ADKAR model helps individuals process change through clearly defined stages that enable them to both understand and accept the changes at hand.

This change management model is a great solution for companies that are trying to look at both the business and people dimensions of change.

Unlike other change management models, this one focuses on the identification and evaluation of the reasons why change is working or not, and why desired results are not being obtained.

It is another model, therefore, which starts from the awareness of the human tendency to resist change, and which focuses on building change one brick at a time.

1.2.5 Kubler-Ross model

Another very famous and completely people-centered model is that of Kubler-Ross. More widely known as the five stages of grief, it is one of those models that were born in a scientific sector other than corporate management but which later found a very favorable reception in it. In fact, the Kubler-Ross change curve can also be considered for planning a change management strategy. In this it is considered a reliable curve above all thanks to the emphasis put on the constant similarities with which people process change in general.

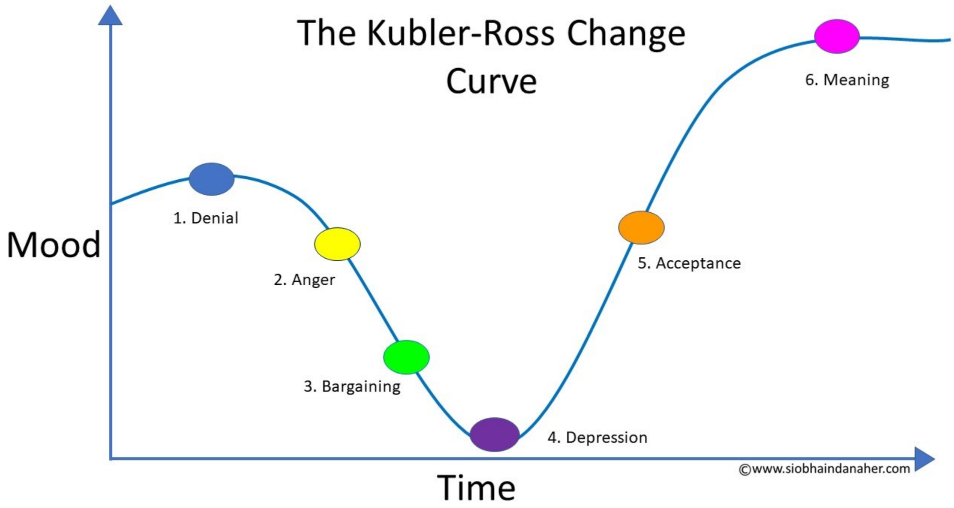


Figure 3:The Kubler-Ross Change curve depending on mood and time.

Organizations can better prepare for change when they also anticipate the possible reactions of their workforce, and it is therefore interesting to report the five phases of the Kubler-Ross model:

- Denial: In this stage, employees are not willing to or unable to accept change. This happens because most people show resistance towards change and may not want to believe what is happening.
- Anger: This model assumes that when the news first get absorbed, anger follows. Denial converts into anger when employees realize that the change is actually happening.
- Bargaining: During the bargaining stage, employees try to get to the best possible solution out of the situation or circumstance. Bargaining is a way for people to avoid ending up with the worst-case scenario.
- Depression: When employees realize that bargaining is not working, they may end up getting depressed and may lose faith. Some of the symptoms

include low energy, non-commitment, low motivation and lack of any kind of excitement or happiness.

- Acceptance: When employees realize that there is no point in fighting change any more, they may finally accept what is happening and may begin to resign to it.

It is a model with which different phases of an individual's life can be considered, from small health problems to the most important and traumatic losses. But, as mentioned, even in business contexts the guidelines proposed by the model can help to face the changes. If teams and companies lose sight of who their changes affect the most, their attempts to make those changes will be in vain. What makes this model important is the importance with which emotional factors are considered.

The five phases, it should be emphasized, although they occur consistently, they do not always appear sequentially. It may happen that a person transits more or less quickly from one phase to another, or that for some the phases are reversed. What matters, therefore, is not an accurate predictive ability, but the importance given to the emotional factor. This highlights how important it is to integrate different change management models, consider or at least know the greatest number of them and then act accordingly based on the peculiarities of the case.

From the models we have reported, it emerges how important managerial skills are combined with excellent communication. Knowing how to communicate the reason for a change, being focused on the goal to be achieved but retaining the essential flexibility in any relationship involving people and the effort to change, are essential qualities for successful change.

2. INTRODUCTION TO ADDITIVE MANUFACTURING

Additive manufacturing is an industrial process employed to manufacture objects starting from 3D computerized models, adding progressive layers opposed to traditional manufacturing that use subtractive production that use mechanical supplies to subtract material in urge to create the desired shape from a block of material.

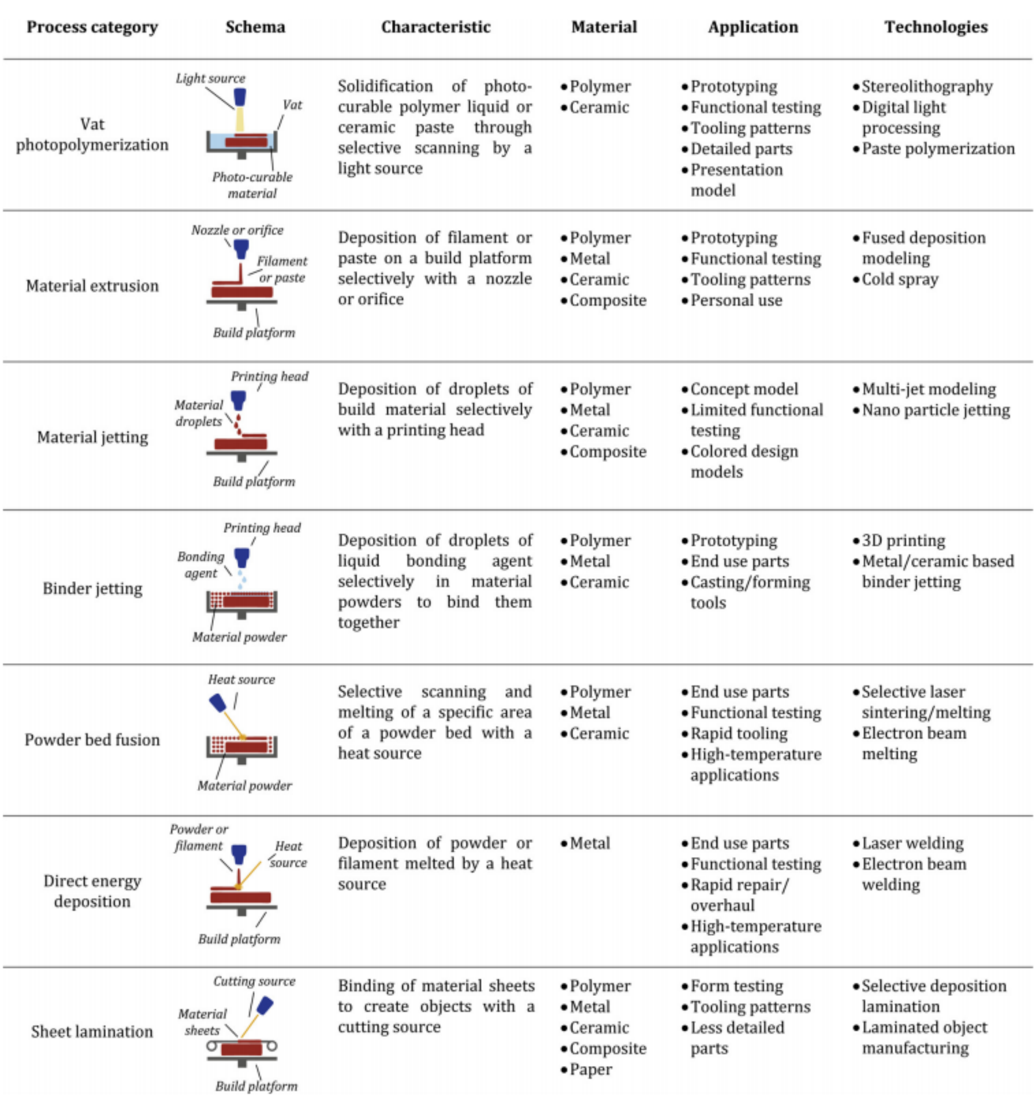
With additive manufacturing it's meant not only the technology of 3D manufacturing but also all the business of implications related to this type of manufacturing that involves economic, financial, logistic and strategic aspects.

3D printing is today, in the context of Industry 4.0, the most disruptive digital technology, capable potentially of disrupting traditional production paradigms.

Additive manufacturing processes all aim to generate a solid, which is why we always start from a 3D CAD drawing which is converted into the format necessary to make it usable for processing. Once the solid has been imported into the machine software, the model is generally divided into a succession of thin layers that will be created in different steps by the machine; in the meanwhile, needed supports are added to the 3D model, using the technology itself, or previously built, which allow the detail not to collapse on itself during production. Finally, after production, the obtained parts can be subjected to post-production treatments, if necessary, among which we find chemical and thermal treatments but also finishing processes on machine tools.

2.1 ADDITIVE MANUFACTURING METHODS

Additive manufacturing processes are in large number nowadays available. Methods of additive manufacturing they differ in the way layers are deposited to create parts, what materials are engaged and what is the operating system behind the scenes.



Process category	Schema	Characteristic	Material	Application	Technologies
Vat photopolymerization	Light source; Vat; Photo-curable material	Solidification of photo-curable polymer liquid or ceramic paste through selective scanning by a light source	• Polymer • Ceramic	• Prototyping • Functional testing • Tooling patterns • Detailed parts • Presentation model	• Stereolithography • Digital light processing • Paste polymerization
Material extrusion	Nozzle or orifice; Filament or paste; Build platform	Deposition of filament or paste on a build platform selectively with a nozzle or orifice	• Polymer • Metal • Ceramic • Composite	• Prototyping • Functional testing • Tooling patterns • Personal use	• Fused deposition modeling • Cold spray
Material jetting	Printing head; Material droplets; Build platform	Deposition of droplets of build material selectively with a printing head	• Polymer • Metal • Ceramic • Composite	• Concept model • Limited functional testing • Colored design models	• Multi-jet modeling • Nano particle jetting
Binder jetting	Printing head; Bonding agent; Material powder	Deposition of droplets of liquid bonding agent selectively in material powders to bind them together	• Polymer • Metal • Ceramic	• Prototyping • End use parts • Casting/forming tools	• 3D printing • Metal/ceramic based binder jetting
Powder bed fusion	Heat source; Material powder	Selective scanning and melting of a specific area of a powder bed with a heat source	• Polymer • Metal • Ceramic	• End use parts • Functional testing • Rapid tooling • High-temperature applications	• Selective laser sintering/melting • Electron beam melting
Direct energy deposition	Powder or filament; Heat source; Build platform	Deposition of powder or filament melted by a heat source	• Metal	• End use parts • Functional testing • Rapid repair/ overhaul • High-temperature applications	• Laser welding • Electron beam welding
Sheet lamination	Cutting source; Material sheets; Build platform	Binding of material sheets to create objects with a cutting source	• Polymer • Metal • Ceramic • Composite • Paper	• Form testing • Tooling patterns • Less detailed parts	• Selective deposition lamination • Laminated object manufacturing

Figure 4: Classification and characterisation of AM process

2.1.1 LASER- BASED PROCESSES

Laser-based additive manufacturing processes use a medium to low power laser source to melt, solidify or cure the material. Laser-based processes can be divided into two subcategories, laser melting and laser polymerization, depending on the phase change mechanism. In laser melting processes, the material is fed in the form of powder either to a powder bed or directly to the processing head via nozzles. A laser beam aim is to melt the material, which cools and solidifies, allowing the part to be manufactured. In laser polymerization usually the material is a photosensitive resin that is cured by irradiation with UV radiation provided by a low power laser source.

2.1.1.1 LASER POLYMERIZATION

All laser polymerization additive manufacturing processes are usually based on the principle of material phase change: a liquid, photosensitive resin that solidifies when illuminated by a (usually low power) laser source. Laser polymerization processes are limited to the production of polymer parts from relatively low-strength resin; therefore, they are more suitable for prototyping and non-structural applications than for the production of structural parts.

Stereolithography (SLA)

Stereolithography is based on the principle of photopolymerization of photosensitive monomer resins upon exposure to UV radiation. The UV radiation source is a low power laser He-Cd or Nd: YVO4, which solidifies a thin layer on the surface. A SLA machine consists mainly of a built platform immersed in a bath of liquid resin and a laser source, including the appropriate hardware and software for control. A layer of the part is scanned by the laser on the resin surface, according to the layer data of the CAD model. After the contour of the layer is scanned, the interior is hatched to solidify it; the platform is dipped one layer deeper into the resin. A blade sweeps over the surface to ensure flatness, and the next layer is built up while simultaneously bonding it to the previous one.

Solid State Curing (SGC)

SGC is a photopolymer-based additive manufacturing technology that uses a powerful UV lamp or laser source through a mask. SGC was developed and commercialized in 1986 by Cubital Ltd. Although the process offers good accuracy and a very high build rate, it is associated with high operating and changeover costs to the complexity of the system.

Thermal Liquid Polymerisation (LTP)

LTP is a process similar to SLA in that the part is built by solidifying successive layers of liquid polymer. However, the polymers used in LTP are thermoset polymers and not photopolymers, so the solidification is triggered by thermal energy rather than light. The thermal nature of the process makes it difficult to control the size of the polymerization zone due to heat dissipation, so parts produced by this process are less accurate. Nevertheless, the process has a relatively high throughput and can be considered for applications where accuracy is not a concern.

Beam Interference Solidification (BIS)

The BIS process is based on the spot consolidation of photosensitive polymers at the intersection of two laser beams with different wavelengths.

The first laser excites the liquid polymer to the reversible metastable state, which is subsequently polymerized by the beams of the second laser. The method is associated with various technical limitations, such as insufficient absorption of the laser radiation at greater depths, shadowing effects of the already solidified material, and diffraction of the laser light, which leads to difficulties in obtaining a precise intersection of the beams.

Holographic interference hardening (HIS)

In this process, a holographic image is projected onto a liquid, light-sensitive polymer that is in a well, so that the entire surface of the polymer is solidified, rather than just point by point. In this respect the process is very similar to that of solid-state curing.

2.1.1.2 ***LASER MELTING***

Laser melting additive manufacturing processes use a laser source to selectively melt a material supplied in the form of fine powder. The material then cools and solidifies to form the final part. The laser beam is directed in the x-y plane using scanning optics while a stage moves in the z-direction.

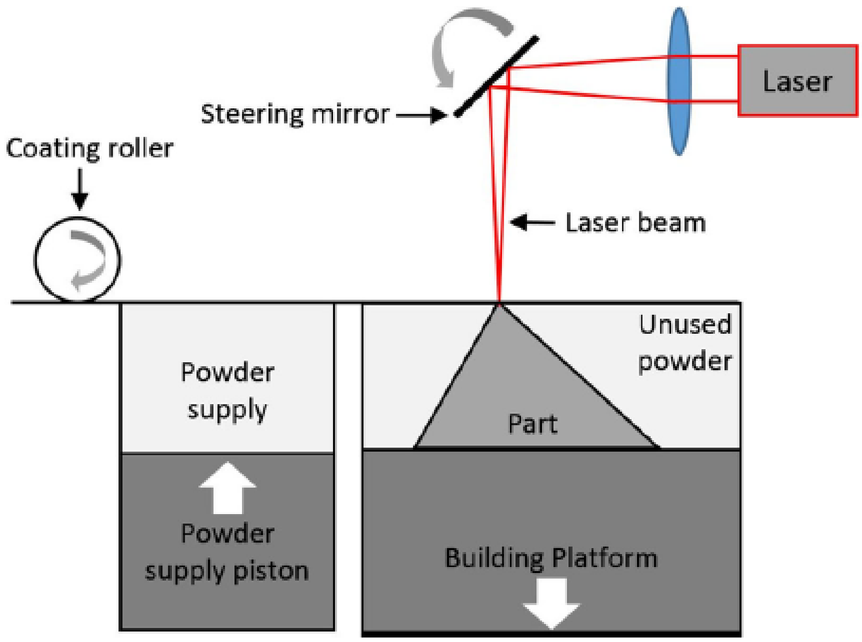


Figure 5: Laser melting AM process schematic

Selective Laser Sintering (SLS)

Selective laser sintering uses a fine powder that is heated by a laser beam so that the grains fuse together. Although the process is referred to as sintering, this is not entirely accurate. Before even the powder is sintered by the laser beam, the entire bed is heated just below the melting point of the material to minimize thermal distortion and facilitate fusion in the previous layer. After each layer is built up, the bed is lowered and a new layer of powder is applied. A rotating roller then ensures that the powder is evenly distributed. The sintered material shapes the part while the unsintered material powder stays in place to support the structure. The unsintered material can be cleaned and recycled after the build is complete. Materials such as metal powder, nylon, nylon composites, sand, wax, and polycarbonates can be used. However, the process is still relatively slow (compared to EBM for metallic structures, for example) and suffers from problems such as uneven distribution of the thermal field, which can lead to thermal deformation and cracking of the product. Nevertheless, SLS is one of the most widely used metal AM processes due to its high accuracy and surface quality.

Selective Laser Melting (SLM)

Selective laser melting is a similar process to SLS; both are instantiations of the same concept, but differ in technical details. Instead of sintering, the SLM process melts powder to form a part. As a result, the laser beam power is usually higher (about 400 W).

Direct Metal Laser Sintering (DMLS)

Direct metal laser sintering is another commercial name used to describe a laser-based additive manufacturing process, similar to SLS/SLM. However, while SLS/SLM can process a variety of materials, DMLS only processes metal powders. DMLS was developed by EOS and is a trademarked name. The typical laser power of EOS machines is 200-400 W.

Laser based net shaping (LENS)

Laser based net shaping uses a high power laser to melt metal powder. A specially designed powder feed nozzle injects the powder stream directly into the focused laser beam, with the laser head and powder nozzle moving as an integral unit. The laser head and powder nozzle move as a single unit. The metal powder is fed either by gravity or with the help of a pressurized carrier gas and distributed around the circumference of the head. The laser beam creates a small molten pool on the substrate or previously deposited layers. The fed powder is consumed in this puddle, increasing the height of the puddle away from the substrate surface. The x-y stage is moved to create each layer of the object. The head is moved vertically upward as each layer is completed. This technique is similar to several trademarked processes, such as DMD, LPD, and SLC.

Compared to processes that use powder beds, such as SLM, objects created with this technology can be much larger, even up to several meters in length; however, the accuracy and surface quality are typically lower.

Direct Metal Deposition (DMD)

DMD is an additive manufacturing technique that uses a laser as an energy source to sinter or melt powdered material (typically metal), where the laser automatically targets points in space defined by a 3D model and fuses the material into a solid structure. The operating principle is very similar to the SLS/SLM process, but lacks a powder bed; instead, the powder is fed directly to the processing head through a number of nozzles (typically 3), similar to LENS.

Laser Powder Deposition (LPD).

In this cladding process, a stream of powder/air is injected directly into the focal point of the laser beam on the substrate. Variants of this process include LENS, SLC, SDM and DMD.

Selective laser cladding (SLC)

Selective laser cladding is another commercial material processing technique in which the laser is used as a heat source to melt metal powder to be deposited on a substrate. This technique is applied as a rapid manufacturing process (RM) to create a point-by-point and layer-by-layer part. It has been introduced as a means of producing functional metal parts with near-net-shape geometries and has a significant advantage over traditional RP techniques. This is due to the direct production of a near-net-shape part compared to the two-step process that involves an intermediate step of mold preparation in traditional RP techniques.

2.1.2 EXTRUSION PROCESSES

Material extrusion processes are use a heated extrusion die to soften or melt the material, usually plastic, in the form of wire. After melting, the material passes through an extrusion die that deposits the material, which then cools to solidify and so to form the final part geometry.

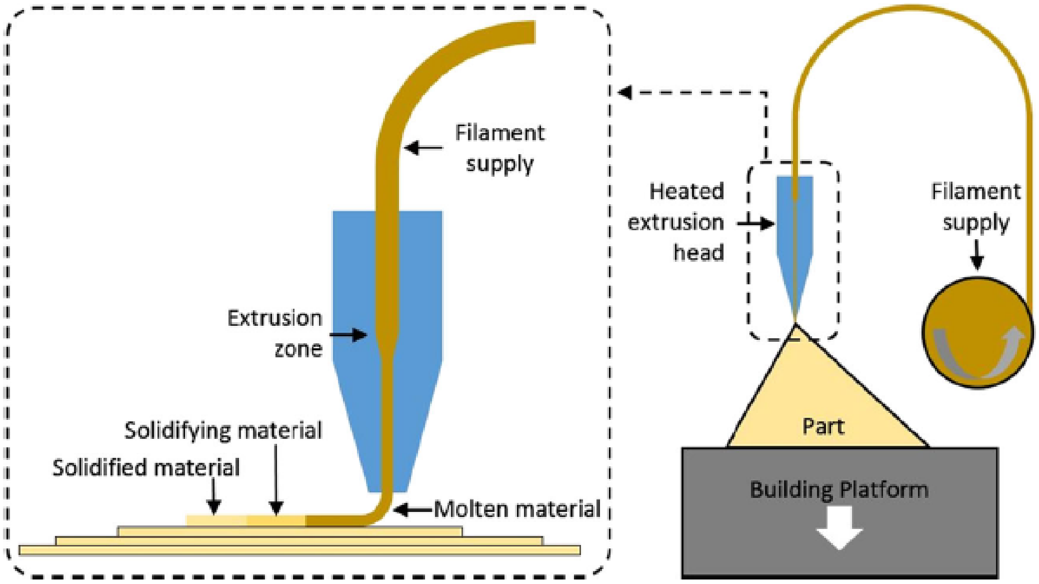


Figure 6: Extrusion AM process principle scheme

Fused Deposition Modelling (FDM)

The FDM technique uses a moving head to deposit a filament of molten thermoplastic material onto a a parts that is the substrate. The material is heated up to 1 °C above its melting point so that it solidifies immediately after extrusion and then welds to the previous layers. The head of the FDM system usually contains two nozzles, one for the part material and one for the substrate material. The advantage of the system is that it can be considered a desktop prototyping system because it uses cheap, nontoxic, odourless materials in a variety of colours and types, such as acrylonitrile butadiene styrene (ABS), medical ABS, PLA, investment casting wax, and elastomers. The simplicity of the FDM process, relatively cheap equipment and raw materials make it ideal for use by hobbys for the production of low-cost plastic parts. Accuracy and surface quality are relatively poor compared to powder-based plastic AM processes.

Robocasting

Robocasting is a free-form fabrication technique based on the layer-by-layer deposition of highly loaded colloidal slurries for dense ceramics and composites. The process is essentially binder-free with less than 1% organic content and parts can be fabricated, dried and fully sintered in less than 24 h.

2.1.3 MATERIAL JETTING

Material jetting processes use thin nozzles to "spray" either molten material or usually a binder (adhesive) in a controlled manner to bind the powder into a solid object. The way it works is similar to all laser melting processes, but there is no phase change, instead the binder holds the powder particles together.

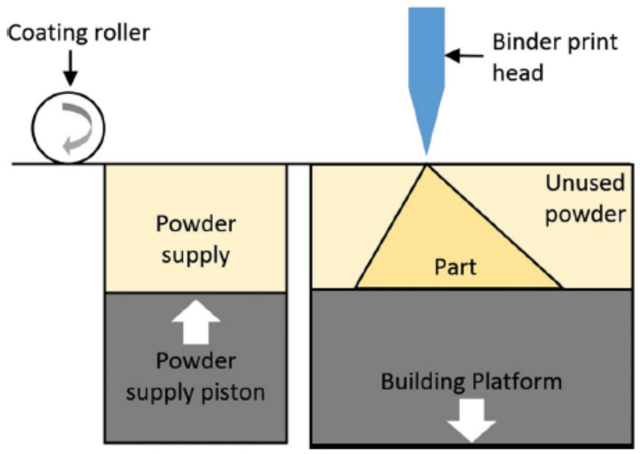


Figure 7: Material jetting AM process

Three-dimensional printing (3DP)

3DP is a layer-by-layer manufacturing process in which parts are created in a flask containing a bed of powder. More specifically, the plunger is gradually dropped and a new layer of powder is spread on top. The part is formed by "ink-jet printing" the binder into the powder.

Ink Jet Printing (IJP)

IJP is a type of AM that produces a digital image by depositing droplets of ink in paper, plastic, or other materials. Inkjet printers are the most commonly used types of printers and range from small inexpensive consumer models to very large professional machines that can cost tens of thousands of dollars or more.

Multi Jet Modeling (MJM)

The principle underlying MJM is the layering principle used in most other RP systems. The MJM builds models using a technique similar to three-dimensional inkjet printing. The MJM head moves in the x-y plane and applies special thermopolymer material only where needed to build a single layer of the model. A UV lamp flashes with each pass to cure the applied thermopolymer. When the layer is complete, the platform is removed from the head (z-axis) and the head begins building the next layer.

Ballistic Particle Production (BPM)

In the BPM process, a stream of molten droplets is ejected from piezoelectric inkjet nozzles and deposited onto the target substrate. The process further uses 3D data from the solid model to position the material stream on the substrate.

Since the process is based on melting the material, it is particularly suitable for the materials, namely thermoplastics and metals, which melt and solidify easily.

Thermojet

Thermojet is a process similar to multijet modeling. The system produces wax-like plastic models, albeit with lower accuracy than SLA. The machine uses a large area head with multiple spray nozzles. These spray heads spray tiny droplets of molten liquid material that cool and harden on impact to form the solid object. This process is commonly used to create casting patterns in the jewelry industry and other precision casting applications.

2.1.4 ADHESIVE AM PROCESSES

Adhesive-based methods are of limited use today. The working principle is that a cutter (usually a laser) cuts a thin film of paper or plastic into the desired contours.The film is then pressed onto the previous one by a heated compressor, which activates a thermosetting adhesive present on the underside of the film to be bonded to the substrate.

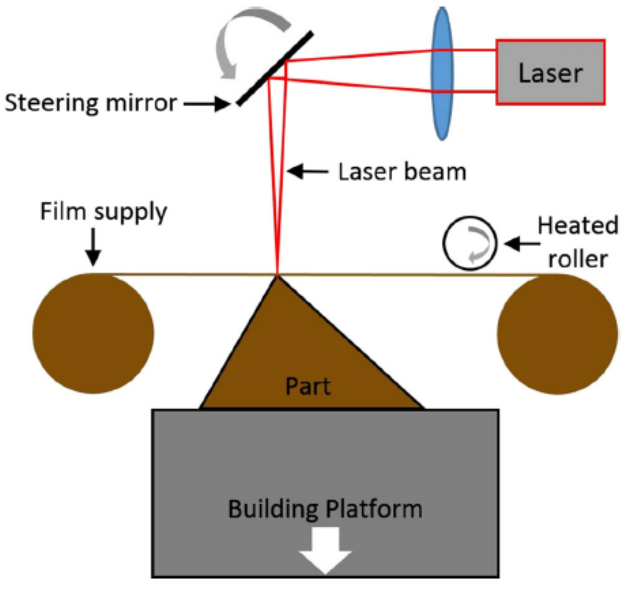


Figure 8: Adhesive AM process

Laminated object manufacturing (LOM)

The material used in Laminated object manufacturing is a special paper with a heat-sensitive adhesive on one side. The sheet is supplied from a roll and is bonded to the previous layer by means of a heated roller which activates the adhesive of the paper.

A CO2 laser cuts the contour of the layer, which is carefully modulated to penetrate exactly one layer (paper) deep. Excess waste material is cut into rectangles to facilitate removal, but remains in place during construction to serve as support. The paper of material used is wider than the build area so that after the partial layer is cut, the edges of the sheet remain intact to be pulled by a take-up reel to continuously provide material for the next layer.

Solid foil polymerization (SFP)

The process is based on the complete polymerization of partially polymerized plastic films upon exposure to a suitable light source. The partially polymerized film is first stacked on the previously solidified part and then exposed to light in such a way that bonding is achieved after complete polymerization. The excess film that is not exposed can be removed by dissolving in suitable solvent, leaving the desired part.

2.1.5 ELECTRON BEAM

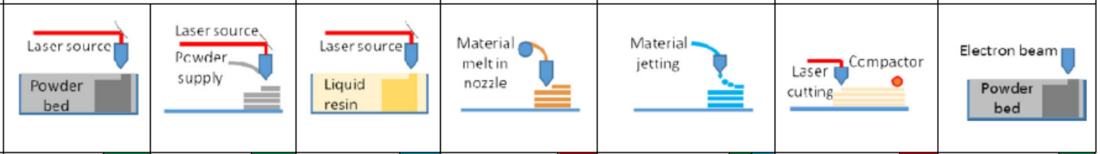
Electron beam processes are identical to laser melting processes, but instead of a laser beam, an electron beam is the energy source to melt or sinter the material.

Electron beam manufacturing (EBM)

EBM is a relatively new but fast-growing process similar to SLS, but only suitable for building metal parts. The powder supplied is melted by an electron beam operated at a high voltage, usually 30-60 KV. The process is placed in a high vacuum chamber to avoid oxidation problems. EBM can also process a wide variety of pre-alloyed metals. Compared to SLS, EBM offers much higher throughput and a more uniform distribution of the thermal field; however, accuracy and surface quality are lower.

Additive Manufacturing (AM) Processes													
Process	Laser Based AM Processes												
	Laser Melting				***Laser Polymerization***		**Extrusion Thermal**		**Material Jetting**		**Material Adhesion**		**Electron Beam**

Process Schematic



Name	Material	Name	Material	Name	Material	Name	Material	Name	Material	Name	Material	Name	Material
SLS	Powder	DMD	Powder	SLA	Liquid	FDM	Solid	3DP	Powder / Liquid	LOM	Solid	EBM	Powder
SLM	Powder	LENS	Powder	SGC	Liquid	Robocasting	Solid	IJP	Liquid	SFP	Solid		
DMLS	Powder	SLC	Powder	LTP	Liquid			MJM	Liquid				
		LPD	Powder	BIS	Liquid			BPM	Liquid				
				HIS	Liquid			Thermojet	Liquid				

Bulk Material Type	Powder (green)	Liquid (blue)	Solid (red)

Figure 9: Additive manufacturing process categorization

3. ADDITIVE MANUFACTURING VS TRADITIONAL MANUFACTURING

The use of AM technologies in different industries has increased and is increasing still these years. In the 20^{th} century Henry Ford introduced the moving assembly line that enabled mass production of identical products. Currently, additive manufacturing enables and facilitates the production of moderate to mass quantities of products that can be individually customized.

Additive manufacturing is opening new opportunities in terms of production and manufacturing. Manufacturing lead times will be reduced substantially, and new designs have a shorter time to market so to meet the customer demand more quickly.

4. CHALLENGES OF ADDITIVE MANUFACTURING

Despite the ongoing growth and benefits of 3D printing, the uptake of AM technologies in many industrial sectors is still limited. Indeed, there are several barriers preventing more widespread adoption of AM in the manufacturing industry:

• the high cost (purchase, operation, maintenance and depreciation) of AM machines and materials;

• the need for more-rapid 3D-printing throughput (new AM technology with faster operating speeds, better resolution and accuracy, larger build volumes, as well as more-optimized loading and unloading procedures);

• the lack of consistency (and maturity) in quality assurance practices across the sector;

• design tools that do not adequately exploit the full potential of AM;

• a general scarcity of suitably trained personnel working in AM, with few opportunities for collaboration and 'cross pollination' of ideas.

These problems thus present several significant ongoing research and industry challenges, across the whole AM process chain. These issues need to be addressed before AM will be economically comparable (or preferential) to traditional subtractive manufacturing approaches in high-value situations. Overall, the entire AM process chain would benefit from faster and cheaper methods, improved industry standards, as well as superior intellectual property protection and security measures.

5. MCKINSEY AND COMPANY TOWARDS CHANGE MANAGEMENT

McKinsey is an international management consulting company that helps thousands of clients make lasting improvements in their performance and achieve their most important goals. Raja Gupta, its leader, was wondering how to best serve their customers using the knowledge of his employees, despite the fact that the company is one of the world's leading consulting firms. However, being that McKinsey received many customers who asked for a service to help decision making, Rupta thought that the decision-making process had to be reviewed, studied and further analyzed to make it truly the spearhead of the company. In the past, the company did not bother to measure, quantify the improvement development of the customers served after the consultancy performed, despite the fact that the improvement was clearly perceived by both parties. Nonetheless, McKinsey noted that moving forward like this would not be competitive and in step with emerging technologies, primarily if her employees weren't geared towards the technology transition. McKinsey and Company then decides to use knowledge management and continuous learning as the key to their productivity. To measure their productivity, they use some guidelines such as stand out, level up and share to create new ideas for new products.

Making knowledge of one's production seems like a utopia; yet, McKinsey has designed the knowledge production line down to the smallest detail by tracing and designing effective communication systems. To do this he has designed a management control system that helps to continuously evaluate the changing business environment based on the needs of the market and customers.

McKinsey wants to ensure that with each process of external change, the organization updates systems to allow it to continue to generate and apply knowledge within the company. He should be ready to modify his activities in response to new insights and knowledge as they arise. To ensure that the entire company is able to benefit from the sharing of knowledge among employees, McKinsey develops a transnational mentality in which it reshapes centralized management models, decentralizing local and global subunits while still maintaining the centralized hub.

Sharing knowledge among employees is economically advantageous because it does not require paid staff dedicated only to training which is a cost advantage. Employee productivity, thanks to the transmission of knowledge, increases at the same cost. At the same time, the learning curve is reduced due to the fact that employees can see all the projects in progress well. The benefits gained from using this value not only benefit McKinsey and Co., but also their customers who will find flexible global services and accurate and latest information.

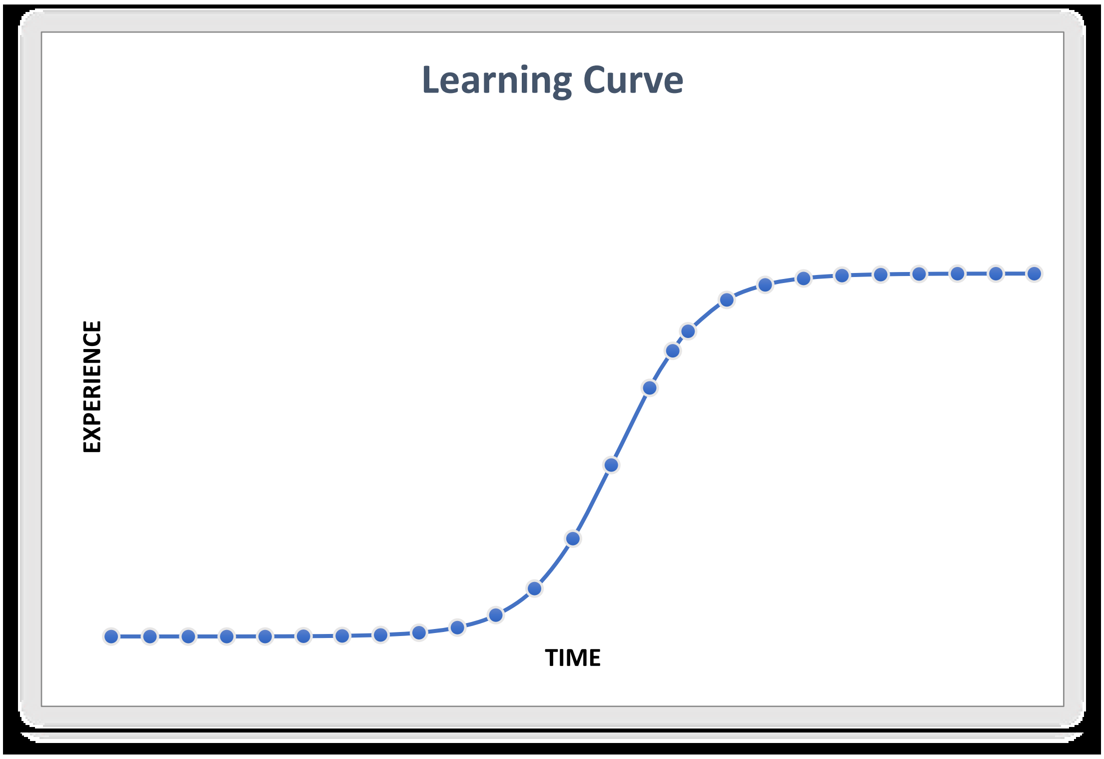


Figure 10: Learning curve based on time and experience.

During the implementation of "knowledge management" three challenges arose that generated three adverse outcomes such as: organizational culture, resistance to change and refusal to accept experts on the subject. In fact, the company placed those who had a master's degree in business administration in a higher level than engineers and other functional figures. Some partners were also very reluctant to accept that functional figures can generate or add value to the company. The manager director however knew that to make things work he had to reorganize the corporate structure by making an integrated organization instead of the generalist company they had. In fact, they wanted to increase the number of specialists and decrease that of generalists.

To avoid internal and external resistance, McKinsey had to make sure to properly manage the organizational structure and information-intensive flow of modern organizations. The managers were responsible for the implementation of “system theory” for the transition from traditional information management “Management Information System” to “Knowledge Management Systems”. A first strategy for implementation was that of outsourcing, but internal resources were still sufficient for the application of the organizational strategy. And doing a cost analysis they assessed that in any case it suited them internally. The difference between MIS and KMS is that the former does not include the assessment of anthropology, cognitive psychology, human resource management, administration, sociology, artificial intelligence, science of knowledge (Mayer 2008). McKinsey has introduced a full-fledged campaign explaining KMS and how it will support business goals.

The strategy of using a KMS to capture and distribute knowledge often requires individuals to contribute their knowledge to a system rather than keeping it to themselves or sharing it directly with known others only through conversation or written face-to-face exchanges. Presumably, some individuals in some organizational cultures follow the dictum that "knowledge is power" by hoarding knowledge and sharing it only when externally motivated to do so. Even willing contributors may sometimes be reluctant to share their knowledge if they do not know who might benefit from the shared knowledge.

Figure 11: Knowledge Management System Chart

6. ADDITIVE MANUFACTURING AND CHANGE MANAGEMENT

We have seen how the transitions towards new management or technological models can significantly benefit from the knowledge of the different approaches to change management. We have also noticed how the human factor is an essential driver in changes and the ability to direct the fatigue inherent in each change towards a goal for which it is worth changing the operational and behavioral patterns of the workforce. This highlighted how important it is to have managers who are attentive to the cultural component, both concerning the motivational needs of workers and the ambitions that lead a company to adopt a change. It can be said that the cultural factor, combined with a continuous need to invest in research (and therefore in the optimization and progress of any process or product) is the basis of change management. We have also considered the Additive Manufacturing process as an example of a technology that presents great challenges towards change. The many application possibilities of this additive technology can be evaluated by the change management managers and eventually implemented. But obviously it must be taken into account how much the (still high) costs associated with the purchase or use of 3D printers can be useful, integrated, and profitable for a given company. Like the change management approach, additive manufacturing manages to have a considerable impact and significant utility only when it is accompanied by constant research. To date, in fact, the sectors in which additive manufacturing is used with a high yield ratio based on investment is that of prototype production, while for the mass production of 3D printed objects there are still improvements that must be done, especially related to the costs to achieve economies of scale with this type of production. Being aware of this state of technology can help change management decide whether to invest in this technology, and possibly also whether to contribute to its development (aiming at a reduction of costs and processes for the future thanks to research or becoming part of those early adopters who by focusing on the development of their business and being successful open new paths for those who will come after them and can be inspired by them).

A company that has invested heavily in additive manufacturing, bringing this technology from prototypical to industrialized use, is Siemens. The problem of industrialization, and therefore of the production of large-scale objects, was one of the major obstacles to the adoption of AM. This is due to the high number of repetitions for the first prints before obtaining a high-quality component for the final product. Very often companies have been forced to print many copies before obtaining a quality one and this approach based on trial and error is very expensive. As Ashley Eckhoff, an expert in AM, marketing and product design at Siemens, affirms:

"*This repeated printing, due to a high failure rate, translates to increased cost. Perfecting a part is a labor-intensive process, with companies printing multiple versions, resulting in a waste of materials and time for each iteration. This scenario is a significant inhibitor to adopting additive manufacturing technologies in an industrial setting […] simulation of the printing process is the best way to reduce the iteration cycle required to achieve high-quality print*".

What Siemens managed to do was to integrate software into its AM-based production system capable of greatly increasing the predictive capacity on the quality of the object before 3D printing.

In November of 2019, Siemens acquired Atlas 3D and their AM simulation tool, Sunata ™. Sunata ™ software uses thermal distortion analysis to provide a simple, automated way to optimize part build orientation and generate support structures. This kind of approach allows the designer, rather than the analyst, to perform these simulations. This has greatly increased the number of first high quality 3D prints, thus reducing costs and paving the way for industrialization. Then a PLM (Product Lifecycle Management) software was developed: NX. Siemens' ambition was to have a seamless process chain that guaranteed high quality products. And so it was: research, development and investments for the specialization of workers led to a seamless workflow, starting from development through to the finished part, thanks to the NX software.

In terms of industrial production, Siemens has been increasingly successful thanks to the printing of gas turbines sold all over the world. In addition, it has also begun to sell its knowledge and acquired and integrated software as a service to other companies, making a profit from the investment they had made before the others.

They also developed an Additive Manufacturing Network, a digital, cloud-based collaboration platform that automates and streamlines the AM workflows of other companies. This allows you to estimate the benefits of a shortened supply chain thanks to AM that would allow companies that want to use the same optimization practices as Siemens to industrialize their processes. This is always thanks to the knowledge and software that Siemens has been able to put together over the years.

An interesting reflection that can arise from what has been said concerns the nature of change. In the end, we always have to deal with prototypes of change, in which the knowledge of several models, their integration and the ability to visualize one half, definitely make the difference. Taking into consideration additive manufacturing as an emblematic case of change in experimentation (and also in industrialization), it can be seen how important investment in research and training is. This is in line with winning change management strategies. But, compared to change management strategies, it can be seen how much easier it is to intervene in the improvement of a production process such as AM "simply" using predictive software that can greatly increase the quality of the first prints, reducing the costs of the expensive production phase. trial and error. Change management cannot use any software that can replace the phase of human adaptation to change, so the strategy can be optimized by the change teams only by accepting that trial and error are inevitable when it comes to workers, and that knowledge of the literature, of the models of change, of the personnel, cannot guarantee a drastic reduction of the costs related to bankruptcy as happens for 3D printers. This highlights how change, and its optimization are much more evident, observable and rewarding in the short term, especially when they are aimed at technical tools. But the related changes in the human approach are equally fundamental.

In the case reported above, AM takes advantage of the advantages offered by simulation software and this can also give a great boost to human change: resources are invested in training specialized personnel to use the new software. The learning curve in the use of 3D printers is thus significantly improved.

Again, we can observe how it is much easier to optimize an AM system than a change management process: relating to specific human realities, rooted in the hic et nunc of the company, is something that only a good change team can do. , taking on risks that are never completely eliminable, even if the knowledge of the possible models and cases of success or failure provided by the literature can help. It industrializes with a change management mentality that, from a predictive point of view, can be brought to the highest levels with regard to objects: but investing in predictive software and specialized personnel comes from a deep awareness of the hybrid nature of change, in which it is always the man to guarantee the success of new tools or new processes.

CONCLUSION

In conclusion, according to my research presented above, research and continuous improvement are two fundamental points to remain competitive. Research in technology, as explained above, especially Additive Manufacturing, is fundamental to the potential it has in the marketplace and will disrupt traditional manufacturing. This will reduce lead time, time for assembly, cost of logistics, etc. In order to survive and more importantly to stand out, it is important for a company to evaluate emerging technologies that are aimed at improving and increasing its competitive advantage.

While in terms of emerging technologies, the "drivers" or methods are more or less identifiable, an important issue to which exact, and optimization models are not very applicable is human resources.

Human resources are essential because they are the ones who apply the models, and it is important that there is positive synergy and involvement for the critical role they play in the business.

Continuous monitoring of the business team is essential as it depends on both internal factors that are specific to each individual and the business or external environment that is also constantly evolving.

Change management cannot suggest a paradigm that guarantees success. It should broaden the operational horizon by evaluating and acting with the awareness that it does not follow predetermined models. On the other hand, change management can be a very useful tool if one takes into account the tools and methods of the literature and thus learns to manage not only the team as a whole, but also the individual, taking into account the many complex parameters such as society, the external environment, the sharing of social values, and so on.

Change management, if properly studied and applied, can therefore be a spearhead in the management of organizations, an important added value to be appreciated.

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Abstract in Italian Language

Il lavoro di questa tesi si divide in due parti, la prima parla di change management e la seconda di additive manufacturing. Nella prima parte tratto il concetto del change management come il processo di pianificazione e coordinamento di individui, team, organizzazioni al fine di consentire una transizione da un assetto corrente ad uno futuro desiderato.

Parlo dei metodi del change management nella letteratura, a partire da Lewin a finire con il modello di Kubler-Ross. In questa transizione il processo di change management deve prendere in considerazione variabili complesse ed implementare le risorse disponibili con il piano o il sistema che ha elaborato. L'implementazione, e quindi la spinta e l'agevolazione fornita dal change management verso questa transizione studiata, nasce dalla necessità di essere reattivi sul mercato e sensibili alla complessità dei sistemi gestionali ottimizzati al meglio. Tra le tante variabili che devono essere consideraste e armonizzate, al change management spetta il compito di ponderare gli effetti del proprio intervento in un ecosistema molto complesso. Per avere un'idea di questa complessità basti considerare solo alcuni elementi che devono essere tenuti in considerazione, come le persone direttamente coinvolte nel processo di cambiamento, la società, l'evoluzione della tecnologia, la concorrenza, i traguardi da raggiungere.

In questa complessità al change management spetta sia un ruolo predittivo (e quindi di analisi e sviluppo) che di agevolazione e gestione verso il cambiamento prefissato.

Nella seconda parte tratto dell'additive manufacturing e dei vari processi di additive manufacturing che esistono. Analizzo i vantaggi e svantaggi di questa tecnologia emergente rispetto alla produzione tradizionale come, per esempio, lo stampaggio ad iniezione.

Il processo di Additive Manufacturing è preso come esempio di una tecnologia che presenta grandi sfide verso il cambiamento. Le tante possibilità applicative di questa tecnologia additiva possono essere valutate dai responsabili del change management ed eventualmente implementate. Ma ovviamente si deve tenere in considerazione quanto i costi (ancora elevati) legati all'acquisto o alla gestione di stampanti 3D possano essere sostenuti, generando profitti per una determinata

compagnia. Anche l'additive manufacturing, come l'approccio del change management, riesce ad avere un impatto considerevole e un'utilità rilevante, solo quando è accompagnato da una ricerca costante.

In conclusione, a seguito dalle mie ricerche sopra esposte, è evidente come la ricerca e il miglioramento continuo siano due punti fondamentali per rimanere competitivi. La ricerca sulla tecnologia, la Additive Manufacturing in particolare è fondamentale per il potenziale che ha sul mercato, posto a sconvolgere la produzione tradizionale. Riducendo così il lead-time, il tempo per l'assemblamento, il costo della logistica etc. È importante per un'azienda, per sopravvivere e soprattutto per distinguersi, la valutazione delle tecnologie emergenti volte a migliorare ed aumentare il proprio vantaggio competitivo.

Mentre per quanto riguarda l'AM, i "drivers" o i metodi sono più o meno identificabili, un punto importante sul quale modelli esatti e di ottimizzazione sono poco applicabili sono le risorse umane.

Il change management non può proporre un paradigma per garantire il successo. Esso dovrebbe allargare gli orizzonti operativi, valutando e agendo con la consapevolezza che non avviene su modelli prestabiliti. D'altro canto, il change management può essere uno strumento molto utile se si tengono in considerazione i processi e metodi proposti della letteratura, tenendo conto dei tanti parametri complessi come la società, l'ambiente esterno, la condivisione dei valori sociali etc.

Quindi il change management, se studiato e usato propriamente un extra valore aggiunto.