Ajuntament de Barcelona

Barcelona Activa

Impact and opportunities of 3D printing on employment

A CLOSER LOOK AT BARCELONA AND CATALUNYA

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Contents

01. What is 3D printing?

3D printing (3DP), also known as additive manufacturing[1], belongs to a group of technologies that enable *Digital Fabrication* and, at its core, it's a manufacturing process that allows objects to be created by progressively bonding small bits of the material of which they are made. 3D printing is steered digitally, meaning that in practice objects modelled in 3D CAD[2] software can be distributed through the internet and then printed physically into the shape that has been defined on screen in a digital 3D model. Currently, there are several 3D printing processes that bring together more than 13 different 3DP technologies that can use a wide variety of materials to transform bits into atoms.

01.1. WHY IS 3D PRINTING SO POPULAR TODAY?

Versatility and flexibility

With 3D printing it's possible to combine different materials to manufacture complex geometries without major changes to the 3D printer

Simplification of manufacturing

3D printing enables the fabrication of virtually any part on the same machine and in one process (one-step process), on demand

Transformation of logistics

Digital information is sent instead of physical objects, which potentially boosts local manufacturing and distribution of products

Customization of products

Due to its digital nature, 3D printed objects can be unique and custom designed to meet customer needs (mass-customization)

01.2. WE MUST DIFFERENTIATE BETWEEN TWO TYPES OF 3D PRINTING

As an initial reference, we distinguish two types of 3D printers according to the physical characteristics of the machines, usage, the difference in the state of development and the opportunities they enable.

Semi-professional 3D printing (*also known as consumer 3DP*)

Driven largely by the maker community[3] and the new digital generation, people use 3D printers and other inexpensive digital manufacturing desktop tools to manufacture small objects (e.g. prototypes, parts, toys, scale models, etc.). It is revolutionary because it virtually allows any individual making objects in your home just by pressing a button.

Industrial 3D printing

Regarded by many as an important factor in driving change to the manufacturing industry, industrial 3D printing has the potential to help companies to increase their competitiveness by reducing time and costs, expanding their production capacities and improving customer service thanks to the exploitation of the its advantages. Additionally, it shows great potential and even current use in the fields of medicine and biotechnology.

[1] As opposed to subtractive manufacturing (traditional processes such as turning or milling, in which the material is removed from a solid block to obtain the final part).
[2] *Computer Aided Design*.
[3] Related to the DIY (*Do It Yourself*) philosophy.

Semi-professional 3D printing

Over 200 different models available

PRICE RANGE 140€ — 4.000€

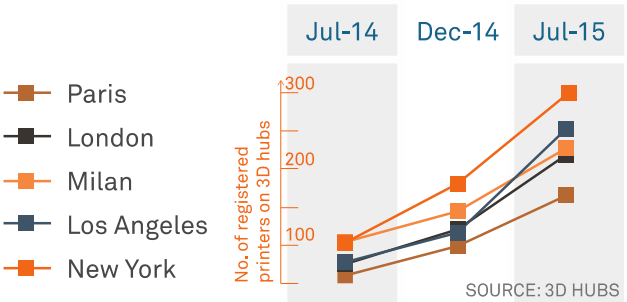
MATERIALS AVAILABLE INCLUDE
ABS, Resin, PLA, Nylon, Composites and Food

WHO IS MOST LIKELY TO BUY?

- Individuals
- Small businesses

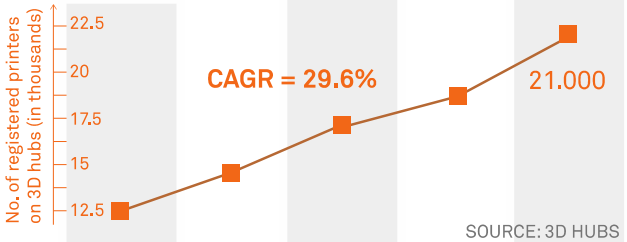
COUNTRIES WITH MOST 3D PRINTERS (2015)

EVOLUTION OF THE NO. OF 3D PRINTERS IN CITIES



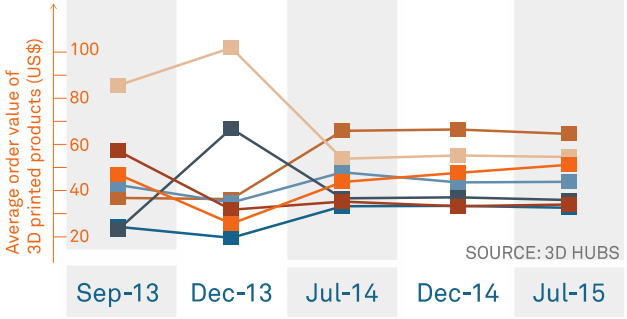
SOURCE: 3D HUBS

REGISTERED USERS ON 3D HUBS*



SOURCE: 3D HUBS

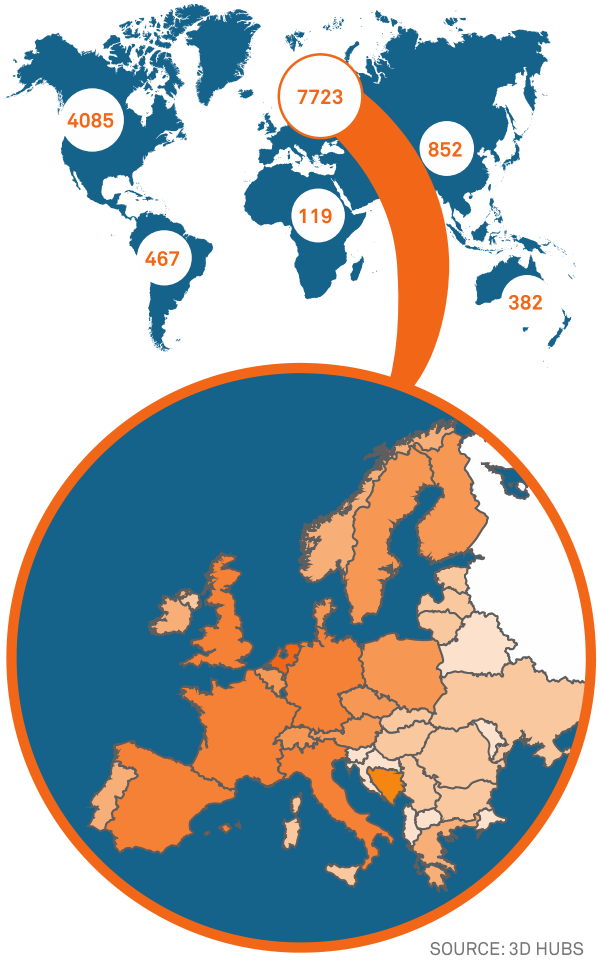
MOST FREQUENT APPLICATIONS AND THEIR COSTS



SOURCE: 3D HUBS

Scale model · Hobby/DIY · Other
Prototype · Gadget
Art/Fashion · Household

NUMBER OF 3D PRINTERS AROUND THE WORLD



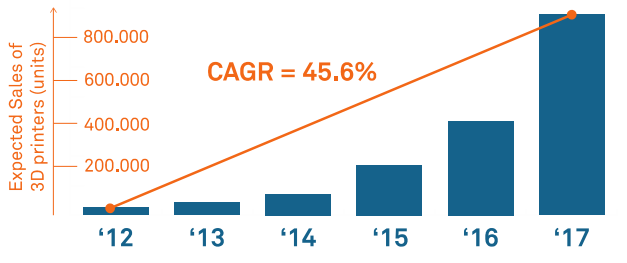
SOURCE: 3D HUBS

DISTRIBUTION OF 3D PRINTERS IN THE EU

<10 · 10-49 · 50-99 · 100—499 · 500—1000 · >1000

"20% of global shipments to western Europe"

EXPECTED SALES EVOLUTION



SOURCE: ANALYSIS OF DIFFERENT SOURCES

THERE ARE OVER 557 FABLABS IN THE WORLD

RELATED TRENDS

REPAIRING, NOT BUYING
CLOUD COMPUTING
OPEN SOURCE
INTERNET OF THINGS
CIRCULAR ECONOMY
SUSTAINABILITY
CITIZEN EMPOWERMENT
CONNECTED HOME
CROWDSOURCING
DIY/MAKER MOVEMENT

* 3D HUBS IS A PLATFORM WHERE PEOPLE CAN REGISTER THEIR 3D PRINTERS ONLINE AND PROVIDE 3D PRINTING SERVICES TO CUSTOMERS THROUGH THE PLATFORM

Industrial 3D printing

Over 50 different models available

PRICE RANGE 4.000€ — >850.000€

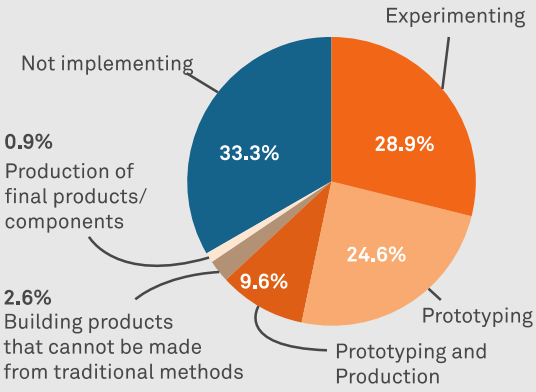
MATERIALS AVAILABLE INCLUDE
ABS, PLA, Titanium, Gold, Silver, Carbon Fiber, Resin, Stainless Steel

WHO IS MOST LIKELY TO BUY?

- Manufacturing Industry
- Medical Industry

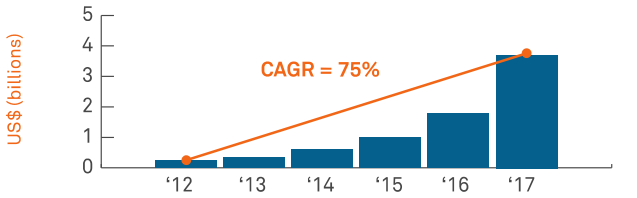
COUNTRIES WITH MOST 3D PRINTERS (2015)

INDUSTRY USAGE



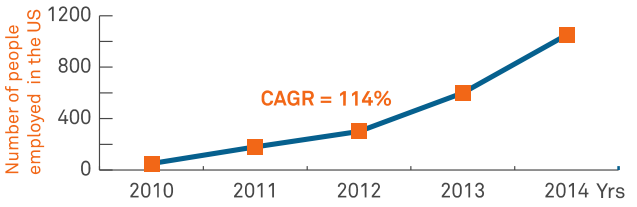
SOURCE: OWN CREATION BASED ON PwC DATA

SALES EVOLUTION OF PRINTERS



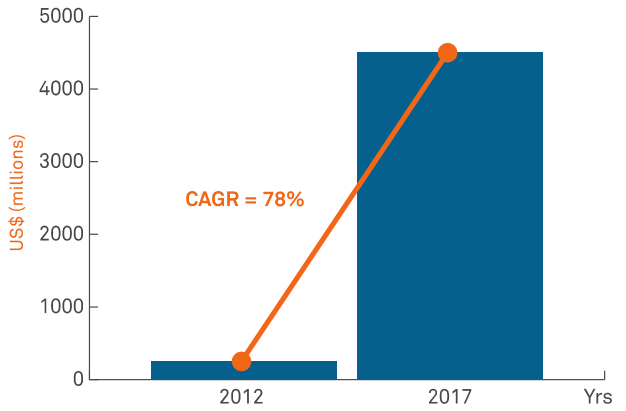
SOURCES: ANALYSIS OF DIFFERENT SOURCES

HIRING TRENDS FOR 3D PRINTING RELATED JOBS



SOURCES: WANTED ANALYTICS

REVENUE FROM INDUSTRIAL 3D PRINTERS



SOURCES: ANALYSIS OF DIFFERENT SOURCES

LEVEL OF IMPACT ON VARIOUS SECTORS

- Textile
- Metal & Machinery
- Construction
- Medical
- Chemical
- Automotive
- Aerospace
- Biotechnology

SOME EUROPEAN REFERENCES

In 2014, 30% of the total units of industrial 3D Printers shipped, were shipped to Western Europe

40% of the large manufacturers are European

3D printing is considered a strategic technology by the European Commission

BARCELONA & CATALUNYA

1 Large multinational company is developing 3DP here

14 Universities and RTD centres doing research

30% Growth in sales for some organizations last year

DOZENS OF COMPANIES USING INDUSTRIAL 3D PRINTERS

26,25 M€ Revenue from companies that have a membership in ASERM* and are based in Catalunya

420 Directly related jobs

SOURCE: ESTIMATIONS BASED ON ASERM DATA AND INTERVIEWS

RELATED TRENDS

Design to be repaired
Internet of things
Digitization of supply-chain
Industry 4.0
Reindustrialization/Local manufacturing
Personalised products
Eco-sustainability

* ASERM = ASOCIACIÓN ESPAÑOLA DE RAPID MANUFACTURING

02. An overview of 3D printing

Every day, through mass media and the Internet, we get to see the latest news and technological advancements in 3D printing which may too often lead us to believe that this technology will be not only omnipotent, but also everywhere. Although inspirational, this situation distorts the reality of this technology and its short term potential, which can bring disappointment. It is therefore important to mind that 3D printing is just *another* technology[4], another *tool* in the digital fabrication[5] arena that is used to satisfy people's needs; not the end goal or the solution in and of itself. *What* is made matters more than *how* it's made.

‹‹3D printing is just *another* technology, another *tool* in the digital fabrication arena that is used to satisfy people's needs; not the end goal or the solution in and of itself.››

02.1. CURRENT STATE OF 3D PRINTING

Think about it: how many of the objects that lay around your home have been 3D printed? Most probably none, unless you happen to be a curious student or a 3D printing enthusiast. Don't worry: you are not to blame. The fact is that semi-professional 3D printers haven't managed to offer the features and characteristics to be massively adopted at home or at small companies yet. Its main users are generally either students or professionals in the fields of engineering, design, architecture or art, or those who are particularly involved in *maker/DIY* communities. It is, in a way, a kind of digital craft.

Semi-professional 3D printing is still, therefore, an emerging trend that requires a degree of technical multidisciplinary knowledge and skills to make good use of it. It also demands an attitude open to experimentation and trial and error, as there is a certain lack of genuinely significant, truly added-value applications that set it apart from traditional methods of fabrication. Is it really worth it to invest a couple hundred euros in a desktop 3D printer that will mostly be used to print pencil holders or a plastic figurine each month? For most people, it is definitely not.

From the need of printing an object without owning a 3D printer have born several Internet platforms inspired by the collaborative economy model where supply and demand can meet. Platforms such as 3DHubs, allow those who own a 3D printer to set up a *fabber* profile and let interested users pay to have an object printed by the *fabber's* printer. This stimulates local fabrication and lets those with advanced 3D printing knowledge and skills help other individuals while making a (small) profit.

‹‹[...] From the need of printing an object without owning a 3D printer have born several Internet platforms inspired by the collaborative economy model where supply and demand can meet. [...]››

Having this in mind, it is interesting to consider the following reflection based on 3D Systems's designer Janne Kyttänen's words: considering that the typewriter didn't make us all writers, neither Photoshop has made us all graphic designers, do we expect 3D printing to turn us into industrial designers or digital craftspeople?

Due to the fact that not everybody has the necessary skills, tools or even the time or will to design objects, online digital model repositories were born. Similarly to 3DHubs, platforms like Thingiverse or Bld3r let those who create digital models of any object share it with the community, either completely free or charging a certain amount depending on its exclusivity.

On the other hand, industrial 3D printing, albeit less known and publicised to the masses, is already proving to be very useful and convenient and therefore having a real impact in the production of goods, especially in the healthcare and manufacturing sectors.

[4] Technically, 3D printing consists of a group of technologies. However, we refer to it as a single technology to facilitate comprehension.
[5] Digital fabrication is a type of manufacturing in which all tools are controlled by a computer.

Did you know?
The Catalan company Avinent, based in Santpedor (Barcelona), is a world leader in 3D printed prostheses and digital odontology.

In the healthcare sector, 3D printing allows for the manufacture of personalised hearing aids (as does GAES), dentures and bone prostheses (as done by Avinent), which makes the sector one of the earliest adopters of this technology. Nowadays there are more than 15 million hearing aids being used in the world.

In the manufacturing sector, industrial 3D printing enables the fabrication of prototypes and tooling on-site and on demand, consequently accelerating development cycles and reducing costs. End-parts –those parts that will be used in real-life conditions and therefore have to meet functional criteria– can be optimized in terms of weight, materials and/or resistance thanks to the fact that 3D printing virtually has no geometrical and design limitations, at a cost that is not necessarily higher if the simplification of both the manufacturing process and the supply chain is factored in. This is why several Catalan companies that work in the automotive sector, for instance, have been using 3D printing in their product development activities for years.

Did you know?
There are close to 10 companies in Catalunya that design and/or manufacture additive manufacturing machines, among which Hewlett-Packard (HP), based in Sant Cugat del Vallès (Barcelona), stands out because of its dimension.

In the industrial 3D printing arena it is important to highlight the importance of companies like Shapeways or Materialise, who offer online, high-quality 3D printing services at a very reasonable price. Thanks to the Internet, virtually anybody has access to the manufacture of the highest quality objects and parts in a varied range of materials and using complex, high-tech equipment that would be otherwise simply out of reach.

Actually, the revolution that digital manufacturing represents is caused by the fact that any person has easy, online access to advanced, high-quality tools that allow them to turn their (new) ideas and designs into reality on a very reasonable timeframe and at a quite affordable price, therefore empowering citizens and facilitating creative entrepreneurship. It is then not so much due to the fact that any individual can make his own objects with his own 3D printer, which is undoubtedly a very excellent aspect anyway.

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The access to high-quality 3D printing services is precisely what enables the existence of start-ups like Nicetrails. This company has created a business model that sells physical scale models –manufactured by a third party via its online printing service– of the GPS geo-localization data recorded by hiker's smartphones as they walk their trails; or Crayon Creatures, a company that sells physical scale models of children's imaginary creatures from a drawing.

02.2. BRINGING MANUFACTURING TO PEOPLE

On of the features that has boosted the popularity of digital fabrication is its inclusive power, as it puts the production of objects and products, once exclusive to companies and owners of expensive equipment, back in the hands of everybody thank to its relatively ease of use and cost of ownership or access.

This very humanistic nature has been officially recognized by the city of Barcelona, that believes in its power to transform and benefit society thanks to the collaborative philosophy to which digital fabrication is closely related. It has been proven through the creation of the

Xarxa d'Ateneus de Fabricació (AdF)[6], a public initiative that seeks the social benefit that comes from its technologically empowered citizens, who have access to free, *democratized production* at these *Ateneus*. This model, somehow comparable to the current public libraries, is a world's first and São Paulo, in Brazil, has already committed to its replication.

‹‹This very humanistic nature (of 3DP) has been officially recognized by the city of Barcelona, that believes in its power to transform and benefit society thanks to the collaborative philosophy to which digital fabrication is closely related.››

The model of having AdFs as a public asset is inspired by the well-known *FabLabs*, roughly their private twin, which are supported by a business model to ensure their financial sustainability. The idea of a FabLab originated at MIT[7] and the Institute of Advanced Architecture of Catalonia (IAAC) was a pioneer in replicating it in Barcelona on 2007.

FabLabs have played and still play a very important role in the dissemination, education and research in this field, which has turned them into one of the most renowned agents in the 3D printing ecosystem in the world and has inspired many other initiatives and businesses such as FabCafé by Makers of Barcelona.

Regardless of what digital fabrication means for businesses, the popularization of these socially focused, highly participative initiatives rooted in the more solid foundation formed by the numerous universities, design schools, RTD[8] centres and companies that have been working with this technology for more than 10 years in Catalunya, is bound to have a very positive effect in citizens of all ages.

There is no doubt that if we take into account how the economy has been evolving over the past decade, increasingly becoming more techy and digitized, any kind of initiative that brings people closer to technology could have a positive effect on cohering society as a whole, boost creativity and motivate students in pursuing a STEM[9] education. Today, STEM-related jobs are necessary to close the existing gap between supply and demand, making them the most demanded in the jobs market and also the ones that offer the brightest prospects for the future.

The combination of such public support, which is also complemented by strategic development programs like RIS3CAT and the Vanguard Initiative, as well as entrepreneurship support programs like FABulous and the existing private venturing, is poised to create an ecosystem of knowledge and opportunities with the capacity to attract both talent and business to Catalunya. This has been proven after Hewlett-Packard (HP) decided to establish its world 3D printing headquarters in their Sant Cugat del Vallès (Barcelona) facilities.

Did you know?
The Barcelona City Hall has created the *Xarxa d'Ateneus de Fabricació*, the objective of which is to grant universal access to technology by placing an AdF in each of the districts of the city. As of late 2015, there are 3 open-to-the-public AdFs.

02.3. A PROMISING FUTURE

All in all, there's quite a generalized consensus in regards to the future of 3D printing: all predictions point to positive growth.

Technological evolution
The most optimistic predictions state that there could be highly integrated and automated, large volume and high-speed 3D printing systems, able to print increasingly widespread, personalized

It shouldn't be too surprising. History has taught us that technological evolution is roughly always the same: with time, products have their specifications improved while their cost decreases. For 3D printing and digital manufacturing, the usefulness of which is proven, the decrease in costs –both for new

[6] Network of Fabrication Athenaeums in Catalan.
[7] El *Massachusetts Institute of Technology* (MIT) is one of the most prestigious polytechnic universities in the USA and in the world.
[8] Research and Technology Development.
[9] Science, Technology, Engineering and Mathematics.

equipment and for consumables– and the improvements in specifications –better print quality, higher printing speed and broader range of available materials– will result in an increase of competitiveness when compared to other manufacturing methods. It is expected that these advancements will be translated into an increased adoption rate, which in turn means boosted sales and economic impact, including jobs. As its possibilities and potential uses increase, 3D printing will gradually absorb the production shares from traditional manufacturing methods, as well as it will enable a shift from productive and business models that are less competitive and often environmentally unsustainable.

Independently of technological evolution, the evolution of production, socio-economic and business models in which these machines will function is also very relevant. In this regard, experts have mixed opinions.

Some have an extensive vision, a vision that expects 3D printers to become common household items, with a penetration similar to current 2D ink-printers: technological progress will bring easy-to-use, reliable machines that will enable massive adoption. In such scenario, most of us will have a 3D printer at home, which will probably also feature a small mill and a laser cutter, which will let us fabricate our own creations or digitally customized objects that we'll download from the internet. In the particular case of food 3D printers, visionaries predict that they will become another kitchen appliance with a penetration comparable to the microwave oven, and they will be used both at home and at restaurants.

A futuristic Barcelona

The idea of a *FabCity*, a futuristic city where production is massively democratized, is still more than 10 years away.

Others believe in a more intensive yet still distributed vision: a reality where production is locally distributed, ending with the current model based in the production of goods in far away countries coupled with massive logistics. Locally distributed production means that urban manufacturing facilities (FabShops) will proliferate in cities, to which consumers will go to buy customized and made-to-order products.

These FabShops, somehow like a futuristic mix of a hardware shop and a copy shop, could offer high-quality, industrial-grade 3D printing services to fabricate products from digital models brought by the customer, or have an exclusivity agreement with a number of companies that provide commercial digital models for them to print.

Will the world's supply chain change?

Although the presented visions are quite different, they seem to be sharing some common ground: both point towards bringing manufacturing back to where consumption takes place. That is possible because initial investments in tooling decrease, and the relative weight of the labour cost is also diminished due to highly automated processes. If such re-location takes place and it is substantial, new business and production models will appear, potentially creating a positive impact on jobs in Europe and Catalunya in the mid to long term.

Although we cannot foresee the future, it is reasonable to expect that the technological progress should bring, in the next 5 or 10 years, a reality in which there is a widespread coexistence of the different tendencies and models. Using a simplified and explanatory analogy, a future similar to the current situation of the traditional 2D printing: there is both a market of domestic and affordable printers that offer basic features and a market of bigger format, higher end and improved quality printers that inevitably sell at an increased price point. Then some of us print at home, while others do it at the office or at copy shops.

If we think about it, it is difficult to imagine that it will be possible or even desirable to print complex and/or critical products in terms of their requirements, especially when they may potentially affect people's health (for example, a car or an organ) with a domestic printer or at a

local FabShop. In that context, would we expect the printers' manufacturers to provide a warranty for products that were fabricated at home?

Consequently, the manufacture of final products with the expected quality and warranty that the consumer expects will be probably obtained by means of industrial 3D printing machines. In addition to being able to fabricate at higher speeds, these printers will have a wide range of usable materials that will enable them to print objects with parts of differentiated properties, they will combine additive and subtractive manufacturing technologies and they will feature integrated surface finishing capabilities.

‹‹[...] although the number of units sold will be higher for the simpler semi-professional 3D printers, industrial 3D printing, impelled by the democratization of its use thanks to affordable online services, will cause a more significant economic impact.››

Considering the significant technological complexity that these advances demand, it is reasonable to expect that although the number of units sold will be higher for the simpler semi-professional 3D printers, industrial 3D printing, impelled by the democratization of its use thanks to affordable online services, will cause a more significant economic impact. Nevertheless, the evolution of the technology will dilute the differences between these two types of 3D printing, even resulting in the creation of the professional 3D printing segment: machines that will be capable of printing objects with a value for money ratio halfway between the industrial printers and the semi-professional ones.

All in all, we're mostly talking about future scenarios that are still from 5 to 10 years away. While industrial 3D printing provides real and tangible results in varied and well-known sectors today, semi-professional 3D printing is surrounded by more scepticism. Questions that will be answered as people increasingly learn and discover the potential of this largely cross-sectorial technology, which will bring more applications and major impact into our everyday life.

03. Opportunities enabled by 3DP in Catalunya

To turn the expected evolution and popularization of digital manufacturing in general (and of the impression 3D particularly) into reality, the ecosystem of organizations working on 3D printing will have to be mature and solid enough, capable of creating the value that users and clients demand by overcoming the technological challenges faced by 3D printing.

03.1. THE CATALAN 3D PRINTING ECOSYSTEM

Catalunya –and especially Barcelona– has a dynamic ecosystem of entities, companies, RTD centres and associations actively working on both industrial and semi-professional 3D printing.

As a reference, the Catalan members of the Asociación Española de Rapid Manufacturing (ASERM), which represent a third of its total, add up to a yearly revenue of around 25 million euros and employ around 400 people. Those, however, do not include any organization working in the field of semi-professional 3D printing and digital fabrication, which is substantially populated and therefore relevant.

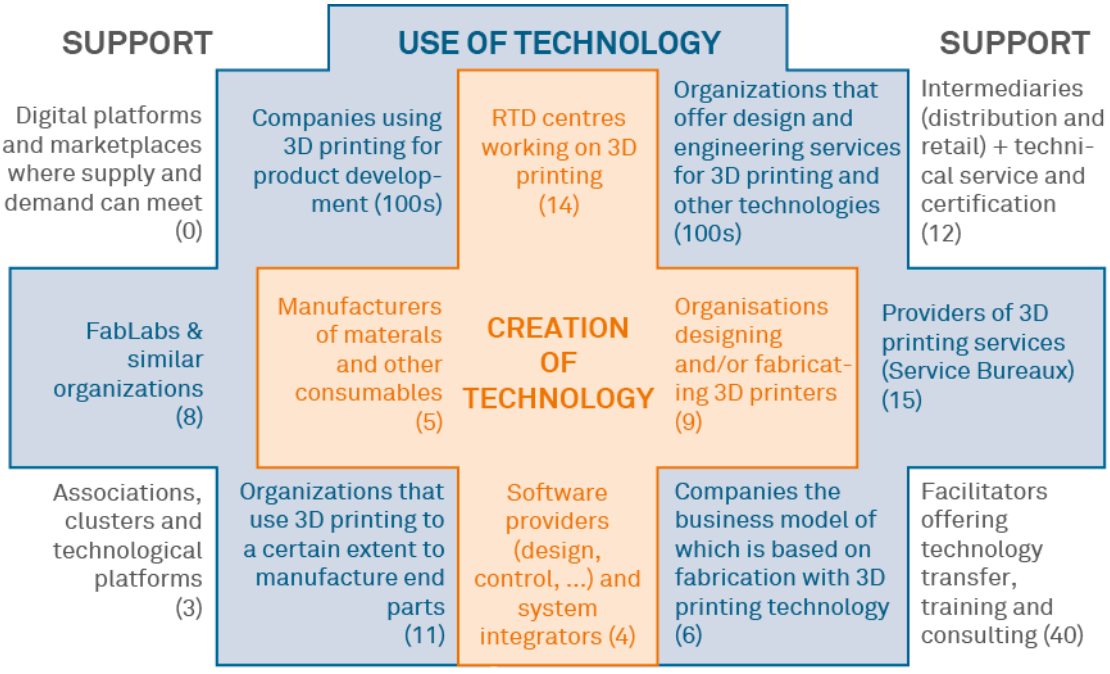
The map of the ecosystem of entities below identifies the types of organizations in the 3D printing industry and offers an estimate on the number of such entities in Catalunya. They are classified in three different groups: creators of technology, users of technology and support organizations.

Creators of technology are the kind of organizations that work on activities related to the research and development of new solutions, materials or components directly related to the printers or the materials used for printing.

Users of technology are those who use 3D printing as a tool to perform their main productive activity quicker or at a lower cost, as well as those who work on non-basic research around 3D printing.

Support entities, lastly, are those who realize activities that facilitate the adoption of the technology and strengthen the ecosystem.

Map of the ecosystem of entities in Catalunya



NOTE: Numbers inside parentheses indicate estimated number. SOURCE: Created by authors based on 2014 data by Leitat

03.2. ELEMENTS OF 3D PRINTING

3D printing is a manufacturing process. As such, the most immediate and clear opportunities come from all those entities that are closely related to the manufacture of both the printers and the objects produced with them.

Nevertheless, we cannot talk about 3D printers and manufacturing with 3D printing without mentioning its design and control software, as well as the range of materials used in the 3D printing process. Although it is sometimes not obvious, 3D printing goes much further than the 3D printer manufacturers and of the 3D printers themselves.

The 3 key elements of 3D printing
We cannot talk about 3D printers and manufacturing with 3D printing without mentioning its design and control software, as well as the range of materials used in the 3D printing process.

Considering the binary nature of digital manufacturing, the availability of specialty software that lets users design 3D objects or control the printers, as well as the code necessary to integrate 3D printing in existing productive systems, is highly relevant. In fact, in an increasingly digitized economy, it is often the role of the platform provider that allows the matchmaking between supply and demand that becomes most strategic: let's think about eBay, AirBnB or BlaBlaCar. These companies neither make nor store products, and they also don't own real estate or cars; they only (but massively) allow the users to find for what they look through the Internet. In the hyper-connected industrial ecosystem of the future, the management of digital information will be an activity of the highest importance; even as important (if not more) as the operation of the machine –3D printer– in and of itself.

In addition to the machine and the software needed for its control: what else is necessary to turn digital models into real objects? 3D printing allows for the transformation of bits into atoms, that is, in materials. The existence of suppliers and organizations working in the development of new materials, especially in the field of the biomedicine but also regarding metallic and composite materials for the industrial sector, will be absolutely necessary to make sure 3D printing meets our highest expectations.

In addition to these key elements, one must also consider the additional portfolio of activities that belong to the 3D printing ecosystem: ranging from 3D printing service providers, which is expected to be the most common business model in the future, to technical support, including retailing and distribution, consulting, training and dissemination, for instance, as well as those performed by unique organizations such as FabLabs or the *Ateneus de Fabricació*.

Although there is significant presence of all such organizations in Catalunya, which cover part of this ecosystem, there is still a need for stronger initiatives and organizations to boost the international relevance of the region. It is therefore necessary to consider the challenges as well as the future opportunities and applications of 3D printing in the different economic sectors.

03.3. THE CHALLENGES OF 3D PRINTING

Semi-professional 3D printing needs to evolve so as to:

- Increase machine reliability
- Improve quality of fabricated objects
- Provide easier-to-use solutions
- Offer added-value applications for the average, non-technical user

In regards to industrial 3D printing, the challenges that have to be tackled are:

- Speed-up 3D printing processes
- Widen the range and the quality of applicable materials
- Reduce costs of printers and available materials
- Improve surface quality
- Increase degree of automation
- Standardize and certify production

03.4. USAGE BY SECTOR

The scope and potential of use of 3D printing is very wide: in general, any sector that uses or produces physical objects is a potential beneficiary of this technology.

On a global scale, experts indicate that the sectors that present and/or will present more and major direct opportunities for the application of the 3D printing are:

Healthcare and biomedicine

Aerospace industry

Automotive industry

Metal and machinery industry

Chemical industry

There is significant presence of almost all of these sectors in Catalonia. However, even though European Agency of the Space (ESA) has deployed a business incubator, it must be noted that most of the companies in this sector are located in other regions of Spain.

In these sectors, 3D printing is used and it is foreseen that will be used to make:

- Scale models
- Tooling, tools and small parts
- Prototypes and product development
- Personalized or customized products
- High added-value industrial parts

Globalized and multi-sectorial impact

In such an interconnected world, it is easy to imagine that the impact of 3D printing will be seen, to a certain extent, in most sectors and in many parts of the planet.

With the aim to offer a more tangible and inspiring perspective, the following table presents a global but not exhaustive vision of the potential of the opportunities and the applications of 3D printing for the different economic sectors identified by Barcelona Activa in the Barcelona Treball website.

These opportunities and applications are framed in a temporary reference that, in spite of being deliberately inexact, aims at showing the speed of the developments in the field of 3D printing and of the needs and job opportunities that they imply.

Opportunities and usage of 3D printing across sectors

SECTOR / FIELD	SHORT TERM	MID TERM (5 YEARS)	LONG TERM (10+ YEARS)
Biotechnology and biomedicine	Medical tools improved thanks to 3D printing	3D printed, personalized medicine	Impressió d'òrgans i teixits complexes
	3D Printing of blood vessels and organs		
Energy and water	Experimental, flexible 3D printed solar panels	Functional 3D printed flexible solar panels	3D printed solar panels integrated in other products
Agro-food industry	First domestic food 3D printers	A 3D printer in every kitchen: print + cook Commercially available ingredients for food 3D printers	Parameterization of nutrient intake thanks to 3DP
Chemical industry (3D printable materials)	Plastics, metals, ceramics, wood, glass, cement... Experimental composites	Organic and biomaterials Functional composites Rare metals and alloys	4D materials Nano-materials

SECTOR / FIELD	SHORT TERM	MID TERM (5 YEARS)	LONG TERM (10+ YEARS)
Logistics	Shortening of the supply chain in many industries Light re-localization of manufacturing		Traditional logistics providers also provide manufacturing services Substantial re-localization of manufacturing
Healthcare	Hearing aid printing Dental and bone prostheses Personalized splints and orthopedic braces	Exo-skeletons and protective gear	3D printers in all hospitals and pharmacies Personalized glasses based on head/skull 3D scan
Social services	*Ateneus de Fabricació* Digital fabrication as part of state-sponsored occupational plans		3D printing of personalized, basic products as a public service
Telecommunications and ICT	Online marketplaces 3D printer control and operation software Industrial system integration	Complex 3D antennas	Advanced and multi-material capable CAD software Distributed production networks
Tourism and hospitality	Customized souvenirs *FabCafès*	Restaurants experimenting with the technology to prepare certain dishes in their menu	New touristic services based on the capacity to manufacture products at the point of sale
Automotive	Design and prototyping Fabrication of rare or discontinued parts	High-end end-parts Tooling Tuned-up vehicles High-end personalized vehicles	Highly transformed value chains Customization of regular vehicles
Wellness and body image	Accessories used to customize fitness equipment Jewelry & accessories		Fully customized fitness equipment
Trade	Small-scale customization of simple products 3D printers for the masses “Do It Yourself” Market	Mass-customization of products FabShops	Integration of 3D printers into traditional shops and retail
Construction	Experimental construction with 3D printed cement Scale models	Free architecture	3D printed buildings on site, with integrated electrical and water/gas installation

SECTOR / FIELD	SHORT TERM	MID TERM (5 YEARS)	LONG TERM (10+ YEARS)
Education	Workshops and courses for enthusiasts Extra-curricular and dissemination activities for people of all ages	3Dd printers in all schools	3D printing as part of the official school program
Aerospace industry	Single, low-weight parts Optimization of critical and unique component through 3DP 3DP of drones and their parts Experiments with 3DP in space	3D printing of aircraft wing structure Completely functional 3DP in space	Wide use of 3DP for space and aircraft parts
Metal and machinery industry	Functional plastic and metal parts Prototyping Molds and tooling	Electronics integrated into 3D printed products Design for reparation through 3D printing Hybrid fabrication = additive + subtractive	Multi-material and big volume 3D fabrication 3D printing of motors and turbines Massive democratization of end-part fabrication
Textile industry	Prototypes and fashion design Exclusive or experimental products	Functional or technical products	4D textile printing
Environment industry	Recycling of plastics for 3D printing Low-volume and niche applications, such as printing of nature-inspired structures to stimulate the recuperation of damaged coral reefs		Industrial 3D printing using recycled materials
Business services	3D printing as a service Consulting and training for 3D printing Self-employed designers offering CAD services for 3DP		Companies dedicated to offer technical support for 3D printing Serious legal issues due to 3DP used for reverse engineering
Smart Cities	FabLabs for enthusiasts *Ateneus de Fabricació*	Popularization of FabLabs/FabShops Urban planning considering implications of urban fabrication	*Data-in-Data-Out* model FabCities
Transport	Transformation of current supply chains	3D printing of toys for long journeys	On-board 3DP of food customized to the passenger's needs Factory in a boat/ship
Culture	3DP used for applied arts, mainly sculpturing Restoration of old objects, heritage and archaeology	Fabrication of accessories for scenic arts	

04. Impact of 3D printing on employment

The impact of 3D printing on employment is still moderate but undeniable and spans, to a different extent, almost all types of identified organizations. It is expected that the opportunities, in general, are more relevant for those professionals who use the technology than for those focused on creation.

The expected evolution is broadly positive, more predictable and more stable in the case of the industrial 3D printing, whereas for the semi-professional case it might end up being yet another tech *bubble*.

On the other hand, ICT and CAD tools are key competences, as well as knowledge in the field of materials and manufacturing processes, hence highlighting the need for certain technical or design training to be able to use the technology.

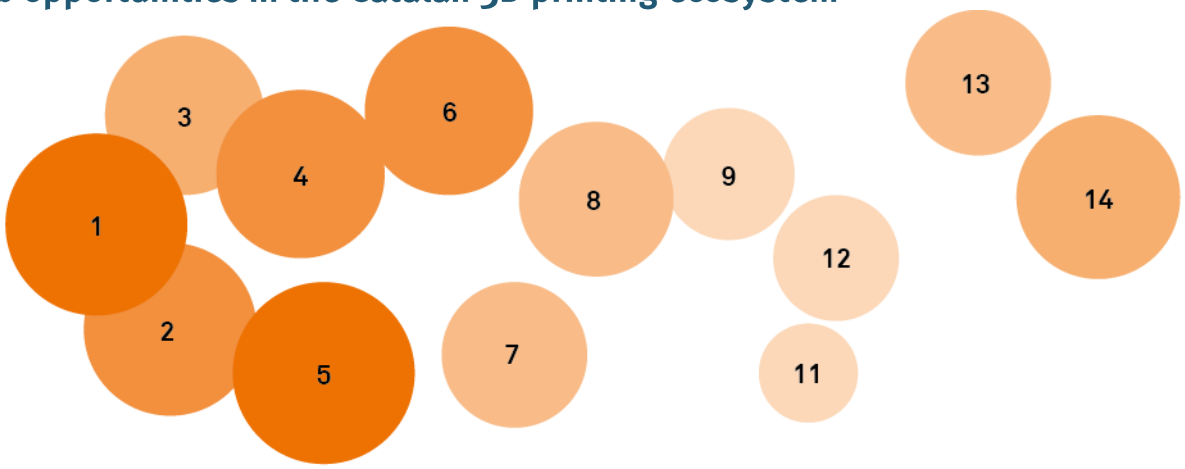
All in all, an impact that will be translated both into the transformation of existing profiles as well as the creation of new ones.

04.1. THE ECOSYSTEM OF JOBS

The creation of jobs and their nature is directly related to the type of activities that companies and organisations in the territory perform.

In this sense, the figure below depicts an estimation of the potential impact of 3DP on employment in Barcelona and Catalonia, synthesized from the evaluations of several experts at national level, and considering the current situation of the sector and the Catalan economy.

Job opportunities in the Catalan 3D printing ecosystem



SHORT TERM — MID TERM (5 YEARS) — LONG TERM (10+ YEARS)

Reference

SOURCE: Own elaboration based on qualitative data from interviewed experts.

1	Companies that use 3D printing for product development	6	*FabLabs* & related entities	11	Creators of digital platforms for offer and demand matchmaking
2	Entities providing 3DP services (*Service Bureaux*)	7	Intermediaries (distributors and shops) + technical service and certification	12	Manufacturers of materials and consumables
3	Facilitators: entities performing technology transfer, training and consulting services	8	Companies with a business model based on manufacturing through 3d printing	13	Software providers (design, control, etc.) and system integrators
4	RTD centres working on 3D printing	9	Manufacturers of 3D printers	14	Organizations partially adopting 3DP to manufacture final parts and components
5	Entities offering engineering and design services for 3DP and other technologies	10	Associations, clusters and technology platforms		

04.2. DIVERSE TIMEFRAMES

Nowadays, jobs creation in Barcelona and Catalonia related to 3d printing is undeniable but not yet significant. The demand is still limited and the local technology creators are still young, even pre-commercial –as a matter of fact, HP has for instance not started yet the commercialization of its long-awaited 3D printers-.

‹‹[...] semi-professional 3D printing is currently at an early stage and [...] a large share of the job opportunities are identified, nowadays, in support activities such as education and dissemination, as well as technology creation –research and development of machinery and materials–.››

There is no doubt that the demand for jobs with skills in 3D printing and digital manufacturing will follow the demand of each sector presented in the previous section. However, the impact on employment will be uneven and desynchronized for the semi-professional and the industrial 3-d printing, given the clearly differentiated current state of the technology and the different evolution expected.

Since semi-professional 3D printing is currently at an early stage and there is still little commercial impact given the limited penetration in the market, a large share of the job opportunities are concentrated, nowadays, in support activities such as education and dissemination, as well as in the technology creation –research and development of machinery and materials–. At the same time, the lack of knowledge of CAD software has also stimulated the demand of design services by individuals or self-employed professionals. In any case, the lack of high added-value applications is nowadays limiting job creation related to the use of 3D printing, something we may expect to change in the mid term, in case it finally does. Currently, those are jobs with an unpredictable future due to the uncertainties linked to the semi-professional 3D printing, which could be experiencing a tech *bubble*.

On the other hand, the maturity of the industrial 3D printing allows for current opportunities to be more tangible, stable and predictable.

Organizations in the field of industrial 3D printing in Catalonia have been active already for some time now, and thanks to the improvement of the technology and the reduction of costs, are seeing their activities to increase up to 30% per year in some cases. This growing trend is expected to remain and rise in the coming years.

04.3. EDUCATION AND SKILLS

In general, those professionals working more directly with 3D printing need crosswise scientific and technical knowledge in the 3 key disciplines that this technology is based on: ICT and CAD, materials and production processes.

Key competences in 3D printing

ICT and CAD: due to the digital nature of the technology and the required tools to design and print in 3D.

Materials: it is necessary to know the characteristics and compatibilities to obtain objects with the desired properties and finishes.

Process: the professional has to decide on the suitability of the technology to achieve the required tolerances and finishes for each case.

Taking this into account, the degree of knowledge and the level of expertise required in one of these fields will depend on the placement in the ecosystem of institutions for 3D printing.

Professionals working in the creation of the technology will need a deep knowledge in one or more of these fields in order to be able to perform R&D activities, usually being those who have scientific/technical background at university, complemented with master's degrees and even PhD's.

Regarding professionals using this technology, they will not necessarily be requested to have such specialised skills, hence allowing for more diverse education backgrounds, including both university and post-university studies, but also Professional Training (PT). Despite the importance of a scientific/technical education,

design skills and the capacity to use advanced CAD 3D software will be very important too.

The most important skill
Given the high pace of technological process in the digital domain, both flexibility and adaptability will be the most important skills in an ever-changing environment.

Professionals working in support organizations will also have diverse education backgrounds: from teachers and professors to experts in management and business development and psychology with university education often complemented with postgraduate degrees in education or business, also including professionals in the field of logistics or others with trade jobs in mechanics, electronics –for technical services– or administration. Professionals having a direct relationship with the technology will need deeper technical knowledge, whereas those involved in more general activities will not need it that much.

04.4. TRANSFORMATION + CREATION

Understanding transformation as the extent to which 3D printing generates changes in the skills and knowledge required to the professional profiles, 3D printing is already having a transformative effect on the jobs market.

The transformation lies mainly in the fact that 3D printing is introduced as a new tool that modifies the existing processes and requires new skills and ways of thinking to take advantage of all the potential. The transformation has a very wide scope, since almost each item identified in the table of applications and opportunities of 3D printing across sectors (p. 13) translates into a need for change in employment or at professional level.

On the other hand, changes in the production model and the new business models that 3D printing enable also have the potential to create new employment profiles that did not exist before. These are occupations that are created in response to new needs and that, given the crosswise nature of 3D printing, they require a combination of skills that can be rarely found in professionals with traditional education backgrounds.

The tables below present a selection of those employment profiles that have seen or will see its functions transformed in a most relevant way as a result of the changes introduced by 3D printing, as well as new employment profiles created or to be created on the basis of new business models enabled by 3D printing.

Jobs that are being or will be transformed by 3D printing

PROFESSIONAL PROFILE	DESCRIPTION	THE EFFECT OF 3D PRINTING	ADEQUATE EDUCATION
METAL & MACHINERY, AUTOMOTIVE AND SIMILAR INDUSTRIES			
Industrial designer Examples of jobs: >*Industrial designer* >*Technical engineer in industrial design*	The industrial designer is in charge of the technical design and development of any product later moving to industrial production, taking into account different types of requirements: functional, usage, ergonomic, technical and esthetical.	He/she will need to consider new possibilities of 3D printing related to materials, geometries and integration of the circular economy and recycling vision. He/she will need to learn to use the software to control printers and other digital manufacturing tools in order to integrate them in the development process.	PT University Technical + Design

PROFESSIONAL PROFILE	DESCRIPTION	THE EFFECT OF 3D PRINTING	ADEQUATE EDUCATION
Engineer Examples of jobs: > *Process engineer* > *Hardware engineer* > *R&D engineer*	The engineer is focused on applying scientific and mathematical knowledge, together with his/her ingenuity, to find a solution for technical problems in the mechanic, electronic, industrial and manufacturing domains.	Understand the operation of different existing 3D printing technologies in order to design, code and manufacture the machinery, as well as managing also production and logistics activities.	University Technical
Software developer and computer systems technicians Examples of jobs: > *Software developer* > *Multimedia developer* > *Systems analyst* > *Systems consultant*	These professionals are in charge of designing and implementing software and systems that enable from machinery control until integration and coordination of those in the production system.	They will need to update their knowledge in order to program interfaces, machinery *firmware* and/or related applications and platforms, such as communication with control systems.	PT University Technical
Product Manager Examples of jobs: > *Product engineer* > *Responsible of business development in the chemical industry*	The product manager is in charge of guiding the developments of a company's products in order to guarantee they address the needs of customers with the appropriate price and features.	Have strategic knowledge of the 3D printing sector, its different technologies and the possibilities that they enable for their products in order to lead to a successful development, enhancing the company competitiveness.	University Technical + business
Responsible of industrial maintenance Examples of jobs: > *Head of maintenance*	The responsible of industrial maintenance is in charge of the proper functioning and operation of the industrial systems and machinery, used by the company to perform its activities.	Due to new deployment of 3D printers in the company, the responsible of industrial maintenance will need to understand the functioning of this machinery in order to identify solutions to technical problems potentially coming up during operation time.	PT Technical
AUTOMOTIVE INDUSTRY			
Moulds and tooling technician Examples of jobs: > *Moulds technician* > *Tooling designer and draughtsman* > *Stamping worker*	The moulds and tooling technician is in charge of designing, manufacturing and maintaining the required elements to be able to produce parts and components through injection, stamping and other traditional manufacturing methods.	3D printing can become both an ally and a threat to these professionals; it can support them for a faster production of moulds and tooling, but it can also imply that these moulds and tooling are no longer needed.	PT Technical

PROFESSIONAL PROFILE	DESCRIPTION	THE EFFECT OF 3D PRINTING	ADEQUATE EDUCATION
Production technician Examples of jobs: > *CAM programmer*	The production technician is in charge of the manual operation of the machinery and the manipulation of the required tools for the fabrication of the company products.	Learn to operate and perform basic maintenance of 3D printing machinery to be introduced as a new tool in the production plant, as well as learn to use CAD software to perform the required adjustments to digital models.	PT Technical
Responsible of automotive spare parts Examples of jobs: > *Head of warehouse*	The responsible of automotive spare parts is in charge of managing the supplies and commercialization of spare parts and components in the automotive sector in order to meet the needs of his/her customers.	3D printing allows reducing stocks and manufacturing spare parts and components when needed, for which professionals of spare parts and components susceptible to be manufactured through 3D printing will need to assess how to update their strategy and portfolio of products.	University Technical or business
Industrial draughtsman/ modeller Examples of jobs: > *2D/3D representation technician* > *Designer of models, mock-ups and prototypes*	Industrial draughtsmen and modellers are focused on creating physical or virtual models of the parts and/or components of the automotive sector according to the specifications required.	3D printing represents a new tool for these professionals, who will need to master it in order to leverage its benefits to accelerate the development cycles and products' fabrication.	PT Technical
CHEMICAL INDUSTRY AND MATERIALS SECTOR			
Materials engineer Examples of jobs: > *Materials engineer*	The materials engineer has an overall engineering background with a specific focus on materials expertise, allowing him to develop new materials and apply them properly to comply with the specifications required.	Materials engineers willing to leverage 3D printing possibilities will need to broaden their knowledge on 3D printing technologies and ICT/CAD in order to anticipate the needs and requirements of the materials.	University Technical
Chemist Examples of jobs: > *Product specialist* > *Chemical production technician* > *Polymers technician*	The chemist studies the composition and structure of the matter and its properties, allowing him to conceive new materials as a combination of basic elements in order to achieve new special properties, beneficial for the humans and its machinery.	The chemist will need to acquire good knowledge on process technologies for 3D printing in order to conceive new materials compatibles to production processes showing the required features to facilitate post-processing allowing the for functional applications.	University Scientific

PROFESSIONAL PROFILE	DESCRIPTION	THE EFFECT OF 3D PRINTING	ADEQUATE EDUCATION
HEALTH AND BIOMEDICAL SECTORS			
Doctor (chiropody, traumatology, otolaryngology, surgery, etc.) Examples of jobs: > *Chiropodist*	A doctor is a professional practitioner of medicine, aiming to keep and restore the health of humans. The medicine is very broad, being divided into medical specialities.	Doctors and odontologists will need to acquire general knowledge about the technology proper functioning and its broad possibilities in order to be able to define new treatment strategies and offer better solutions to their patients. This may include the usage of 3D scanners and/or printers, as well as complementary software for the design and manufacturing of splints, insoles or hearing aids, for instance.	University Health
Odontologist Examples of jobs: > *Odontologist* > *Odontologic researcher or teacher*	The odontologist is the professional in charge of improving oral health of the population. He/she has a solid ethical, medical and social education. He/she leverages the scientific method to diagnose and treat the patient.		University Health
Nurse Examples of jobs: > *Out-of-hospital emergency nurse* > *Manager of nursing services*	The nurse works at intensive medicine and emergency services, taking care of patients attending them. He/she performs an evaluation of the patient status and provides different medical treatments.	The nurse will need to learn to use 3D scanners, design software and 3D printers so the hospitals can offer an on-site manufacturing service of splints and other personalized objects to support the medical treatment.	University Health
Biomedical or biomaterials engineer Examples of jobs: > *Researcher in biomaterials* > *Biomedical engineer in robotics, image diagnosis and telemedicine*	The biomedical engineer gathers knowledge mainly in engineering, medicine and also basic understanding of physics, chemistry and biology. He/she is the link between medicine and engineering, transforming the needs of the doctor into technical specifications of the systems he/she designs and develops.	The biomedical engineer will need to strengthen his/her knowledge in CAD tools, materials, biomaterials and manufacturing processes in order to provide with solutions required from doctors by designing and developing new tools and technological products for the health sector.	University Technical and health
OTHER RELEVANT SECTORS			
Chef, cook and cuisine professional Examples of jobs: > *Chef* > *Pizza cook* > *Restaurant pastry chef*	The chef is the professional that handles, prepares, conserves and presents all class of food depending on the gastronomic offer. He has to consider established guidelines of quality and economic profitability and apply safety and hygiene regulations that can be demanded.	In order to be able to benefit from possibilities of food printers, cooks will need to understand properly the functioning of machinery and, particularly, the behaviour of each printed ingredient. In order to make their ideas come true, they will also need to learn to use CAD tools.	PT University Alternative Gastronomy and others

PROFESSIONAL PROFILE	DESCRIPTION	THE EFFECT OF 3D PRINTING	ADEQUATE EDUCATION
Social teacher and educator Examples of jobs: > *Social educator* > *Director of studies*	Teachers are devoted to guiding the learning and education process of students they are in charge of, including giving a course, applying specific didactics, evaluating and certifying the knowledge acquired by the students and, often, performing a follow-up process personalized per student. Social educators perform socio-educational activities with socially excluded people due to origins, cultural or personal reasons, hence with troubles to integrate themselves back into the community.	It is required to know properly a technology in order to provide training and educational integration into social programmes. Although those teachers with technical profiles will be the first ones to get involved with 3D printing, technology spread as a useful tool for health, design and social services domains will push teachers to learn how to design objects and handle 3d printers if they want to use them in their courses and programmes.	University Diverse knowledge areas
Architect, civil engineer, urban planner Examples of jobs: > *Technician in buildings refurbishment*	Architects, civil engineers and urban planners are those professionals in charge of planning, designing, projecting, building and refurbishing constructions, infrastructures and urban spaces that match with the needs of potential users, improving the coexistence and comfort, taking into account social, environmental, historical, aesthetic, geographical and functional aspects.	Architects and civil engineers will leverage 3D printing to materialize their ideas on scale allowing to validate and improve them quickly, encouraging them to explore new geometries and approaches, and enabling new possibilities in terms of materials and construction methods. Urban planners will need to take into account how digital manufacturing will transform the model of cities and their uses when planning their organization.	University Technical and Humanities
Artist, jeweller, fashion designer and arts and culture professional Examples of jobs: > *Accessories and complements designer* > *Goldsmithing and jewels designer* > *Restorer of musical instruments*	Art and culture professionals leverage their creativity to conceive, design and materialize their products and masterpieces making use of specific and diverse techniques and procedures. Their masterpieces can either be handcrafted or products manufactured with industrial procedures.	3D printing is a technology with a strong artistic component. Jewellers and sculptors are already leveraging it to design and manufacture new pieces, forcing them to develop skills in CAD design and acquire knowledge of the processes and materials available in order to make their ideas and projects come true. We are referring somehow to craftsmen of the digital era.	PT University Art, Design, Fashion, Craftwork and Professions

New kinds of jobs created by 3D printing

PERFIL PROFESSIONAL	DESCRIPCIÓ DEL PERFIL I LES SEVES ACTIVITATS	FORMACIÓ ADIENT
FabLab or co-creation space staff	The *FabLab* staff is somebody with advanced multidisciplinary knowledge on digital manufacturing, including: programming, design, materials and diverse manufacturing processes (laser cutting, traditional tools, 3D printing, etc.), that he/she applies to both research and develop his/her projects as well as provide support to users of the *FabLab* or co-creation space he/she is employed at. He/she does client-facing work and also organizes activities and workshops, as well as offering training courses or consulting services in digital manufacturing.	PT and/or University Technical, Arts or others
Maintenance technician of 3D printers	The maintenance technician in 3D printers is the professional that has acquired advanced practical knowledge about one type or family of 3D printers (often from one or manufacturers) that allows him/her performing their maintenance and repairing activities. He/she usually works at companies focused on the commercialization of machinery from these same manufacturers.	PT Technical
3D printing consultant	New possibilities enabled by 3D printing in a wide range of sectors create the need of professionals capable to identify and evaluate particular opportunities for each company and organization. The 3D printing consultant will have a broad knowledge of the technology, and related costs and business models, and he/she will have an overview of the sector, allowing him/her to advice at strategic and operational level.	University Technical and/or business
FabShop staff	Similar to the *FabLab* staff or co-creation space in the sense that both will do client-facing work, but unlike him/her he/she will not need such advanced technical knowledge in digital manufacturing. His/her tasks will be focused on operating and keeping the proper functioning of machinery deployed in the facilities he/she is employed at, keeping defined and standardized processes and guidelines in order to manufacture products that the *FabShop* user will acquire at once.	PT Technical

04.5. OPPORTUNITIES IN ENTREPRENEURSHIP AND SELF-EMPLOYMENT

Entrepreneur with an activity based on 3D printing: The entrepreneur who bases its activity on 3D printing takes full advantage of the new production paradigm exploiting it through the definition of new or revolutionary business models. Although he/she will usually have advanced knowledge in one or more key areas for this technology (ICT, materials, design or manufacturing processes), this will not necessarily be the most important point; the entrepreneur will need to acquire knowledge in business and strategy, marketing and human resources in order to grow his/her business and ensure its long-term competitiveness.

Self-employed working on 3D printing: The fact that advanced knowledge of 3D CAD tools is essential to be able to manufacture objects through 3D printing will force the self-employed working on 3D printing to adopt often the profile of an industrial designer. He/she will have a solid practical knowledge of the materials and will be focused to design and commercialize either his/her own designs through online platforms, or will work for individual customers in the context of a project. The self-employed will have technical and/or design background, usually acquired at university but also online or through alternative training.

05. Conclusions

- ✓ 3D printing is a transversal technology that presents new possibilities and has the potential of complementing and even breaking with the status quo of many different sectors.

- ✓ Industrial 3D printing provides real and tangible results in varied and well-known sectors today, mostly in industrial and healthcare/biotechnology sectors. Its evolution is therefore more predictable and is expected to follow a positive trend as more companies use it and high-quality, online 3D printing services increase their popularity.

- ✓ Semi-professional 3D printing is surrounded by scepticism and many questions that still demand answers, which is why its future is rather unpredictable: the scenario where everybody has a 3D printer at home is still quite a dream. Technological evolution and its ability to bring added-value applications with major impact into our everyday life will determine its future.

- ✓ We cannot talk about 3D printers and manufacturing with 3D printing without mentioning its design and control software, as well as the range of materials used in the 3D printing process. Catalunya –and especially Barcelona– has a dynamic ecosystem of entities, companies, RTD centres and associations actively working on both industrial and semi-professional 3D printing. However, there is still a need for stronger initiatives and organizations to boost the international relevance of the region.

‹‹ Catalunya –and especially Barcelona– has a dynamic ecosystem of entities, companies, RTD centres and associations actively working on both industrial and semi-professional 3D printing.››

- ✓ Regarding Catalunya, experts indicate that the sectors that present and/or will present more and major direct opportunities for the application of the 3D printing are:

Healthcare and biomedicine

Automotive sector

Metal and machinery industry

Chemical industry

- ✓ Current impact of 3D printing on employment is still moderate but undeniable. A positive evolution is expected, which is more predictable when it comes to industrial 3D printing than it is for the semi-professional kind, as the latter could even be a sort of *bubble*. It is expected that job opportunities will generally be greater for those using 3D printing rather than for those creating the technology itself.

- ✓ In regards to skills, having a working knowledge on ICT and CAD tools (crucial for design-centred jobs), as well as in the fields of materials and manufacturing processes will be very important. Technical (STEM) or (industrial) design education will be the most demanded backgrounds to be able to work on 3D printing. Nevertheless, given the high speed of technological evolution in the digital field, flexibility and adaptability will be the most valuable skills in a world of constant change.

- ✓ The impact of 3D printing on employment will be seen in both transformation of existing professional positions in a variety of sectors and the creation of new positions due to new business models and needs. Entrepreneurship and self-employment, on the other hand, will also be highly relevant in the 3D printing arena.

‹‹ The impact of 3D printing on employment will be seen in both transformation of existing professional positions in a variety of sectors and the creation of new positions due to new business models and needs. Entrepreneurship and self-employment, on the other hand, will also be highly relevant in the 3D printing arena.››

06. Complementary resources

06.1. BOOST YOUR SKILLS IN 3D PRINTING IN CATALUNYA

Get to know some of the organizations that offer training and education in 3D printing in Catalunya:

06.2. GET TO KNOW THE 3D PRINTING ECOSYSTEM IN CATALUNYA

There are lots of different organizations working on or with 3D printing in Catalunya. Some of them are:

06.3. KEEP YOURSELF UPDATED AND ENGAGED

The world of 3D printing is much wider than this report; discover and engage both online and offline.

Spanish website dedicated to the world of 3D printing: news, jobs, training, ...

Beginner's guide on *3D Printing Industry.com*, where job offers and other information can also be found in English.

Article about the *FabCity* model for Barcelona, by Tomas Díez (FabLabBCN).

A series of worldwide events devoted to the philosophy and fans of the Do It Yourself trend.

3Dprint.com is an English-speaking website dedicate to 3D printing and its applications.

Worldwide events around 3D printing. An event in Barcelona will take place in 2016.

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